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A STUDY OF THE FEASIBILITY OF USING ROADSIDE RADIO COMMUNICATIONS FOR TRAFFIC CONTROL IN AN URBAN ENVIRONMENT

A THESIS

Presented to

The Faculty of the Graduate Division

by

Andrew C. Kanen

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of the Requirements for the Degree

Master of Science in Civil Engineering

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A STUDY OF THE FEASIBILITY OF

USING ROADSIDE RADIO COMMUNICATIONS

FOR TRAFFIC CONTROL IN AN URBAN ENVIRONMENT

Approved:

Chairman

Date approved by Chairman: May 15, 1966

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CHAPTER I

INTRODUCTION

The continued demand for increased capacity to carry larger volumes of traffic at higher speeds and in greater safety on the existing and future highway network, emphasizes the need for improved communications for traffic control and regulation so as to expedite vehicular traffic on our road and street system. A reliable communication system, providing guidance, warning and regulatory information under all the highly varied physical conditions of our highways, could be composed of a single communication system. However, it appears more likely that several subsystems or modes of communications, with each subsystem providing specialized functions or adaptations, may be developed and coordinated to provide a reliable overall system.

Purpose

The objectives of this research project can be summarized as follows:

The primary objective was to evaluate the effectiveness of the roadside radio communication system on the decision-making process of the driver as related to his execution of a traffic maneuver, such as a merging or diverging maneuver from a freeway traffic stream, and to evaluate the effect of the driver's decision process relative to his familiarization with the physical configuration and traffic conditions of the highway facility.

A secondary objective was to evaluate the effectiveness of roadside radio communications as a warning and informational device on a freeway system in an urban environment.

To accomplish the objectives an experiment, involving a series of individual tests, was designed. For the primary experiment five different test conditions were developed, each with different combinations of visual and audio guidance information to be provided at a specific freeway exit ramp. Test vehicle speeds and placements were measured at various positions along the highway to determine differences between driver performances in the execution of a diverging maneuver from the freeway under the different test conditions. Each of the five tests were repeated three times with the same test drivers to allow the evaluation of the effect of driver familiarization with the physical characteristics and traffic conditions of the highway facility.

A secondary experiment was conducted concurrently with the primary one and consisted of providing test drivers with audio messages concerning simulated roadside activities for which the provision of roadside warning signs is frequently impractical. A test involving the broadcasting of general route information was included in this experiment. The secondary experiment was of major importance also in "screening" or "masking" from the participating test subjects the project objective of the primary experiment.

Review of Previous Research

Prior to the research in roadside radio communications conducted in 1963 at the Experiment Station of the Georgia Institute of Technology,[1*] research regarding this mode of communication was very limited and was not organized or controlled experimental research to evaluate radio communication as part of a comprehensive highway communication system.

The research conducted at the Georgia Institute of Technology in 1963, referred to above, is briefly summarized here. Random samples of test vehicles from the general motoring public were selected at a point along a rural freeway. These vehicles were equipped with radio receivers and the drivers received audio information on accidents, typical highway maintenance activities, and route information, while traveling through a test section. Data on traffic flow were collected by the use of time-lapse photography and in addition test vehicle operators were interviewed at the end of the test section.

Results of the experiments showed that radio communication is an effective device for controlling vehicle speed in hazardous areas as indicated by significant differences in speeds between test and control vehicles at locations of potential hazard along the test section. The interview data revealed that motorists considered radio communication a useful device and that it should be used in a variety of situations providing various types of information. Driver acceptance of this system of communication was indicated by the amounts drivers were willing to pay for a receiver capable of receiving such roadside broadcasts, based on the assumption that this receiver would be constructed as an integral part of the usual car radio and would work automatically whether his

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*Numbers refer to references listed in the Bibliography.

radio was on or off and could be used on all of the major state highways. Over 75 per cent of the drivers in each of the four tests conducted were willing to invest from fifteen to thirty dollars in such a radio system. Considering all four tests together approximately 92 per cent of the drivers indicated they would be willing to purchase such a system.

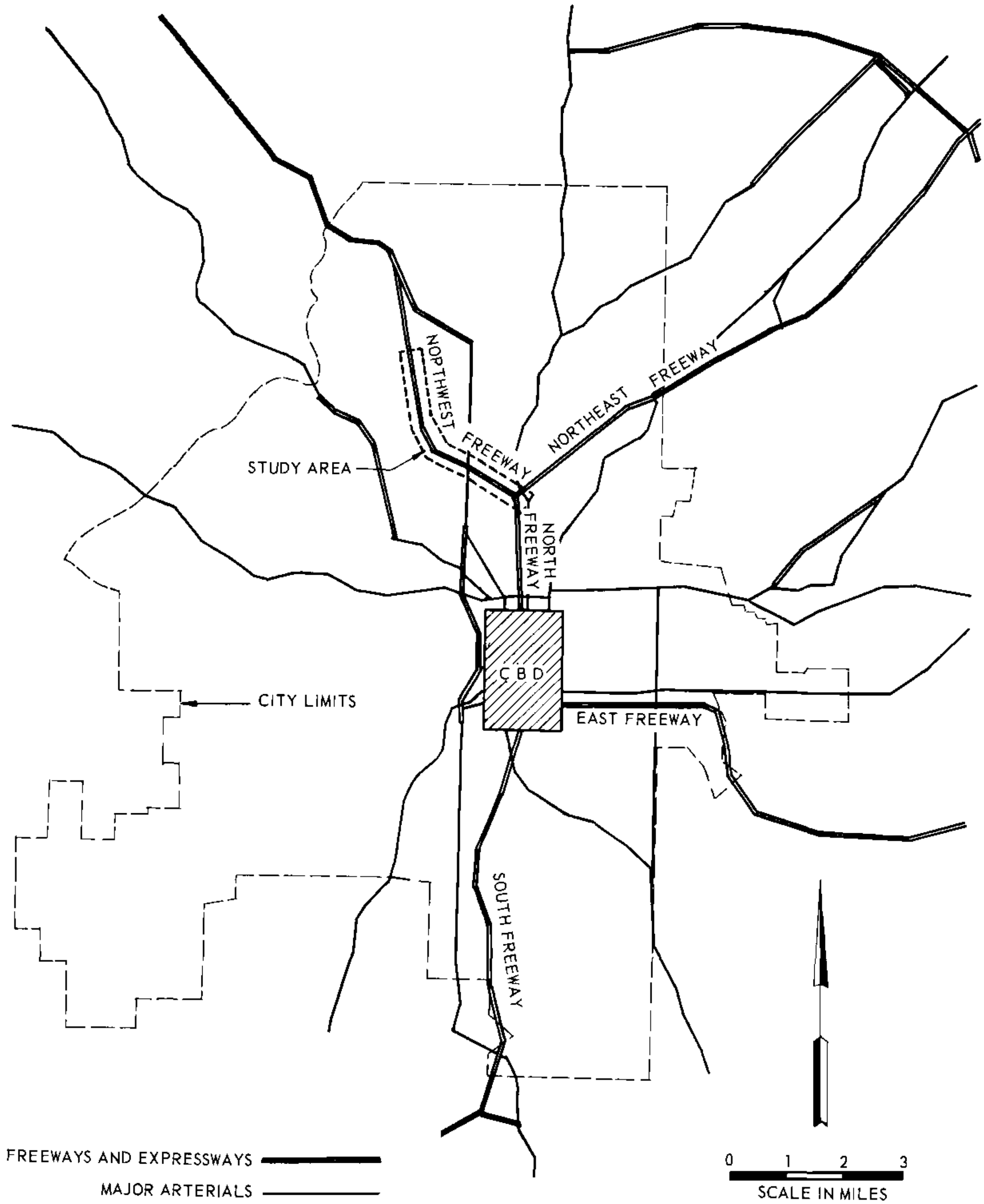

Figure 1. Atlanta Freeway System and Location of Study Area.

CHAPTER II

DATA COLLECTION

Study Site

The objectives of the research required a study site which met the following basic conditions: one, that the facility reflected typical present day freeway design, and two, that traffic volumes on the facility and the exit ramp were sufficient to present a real traffic situation but not of a magnitude to produce congestion or severe limitations on individual freedom of maneuverability.

The several freeways in the Atlanta metropolitan area were evaluated. A section of the Northwest freeway, designated Interstate Route 75, within the urban limits of the city of Atlanta was selected as the locale for conducting the proposed experiment. Figure 1 shows the existing freeway systems in the Atlanta area and the location of the study site.

Sections of the Northeast and East freeways under consideration as possible sites were rejected on the basis of excessive traffic volumes, geometric characteristics and problems of convenient accessibility for a majority of the test subjects.

The study section of the Northwest Freeway selected for the purpose of conducting the experiment is approximately four miles in length and extends from the junction of the North and Northeast Freeways in a northwesterly direction. Three interchanges are located

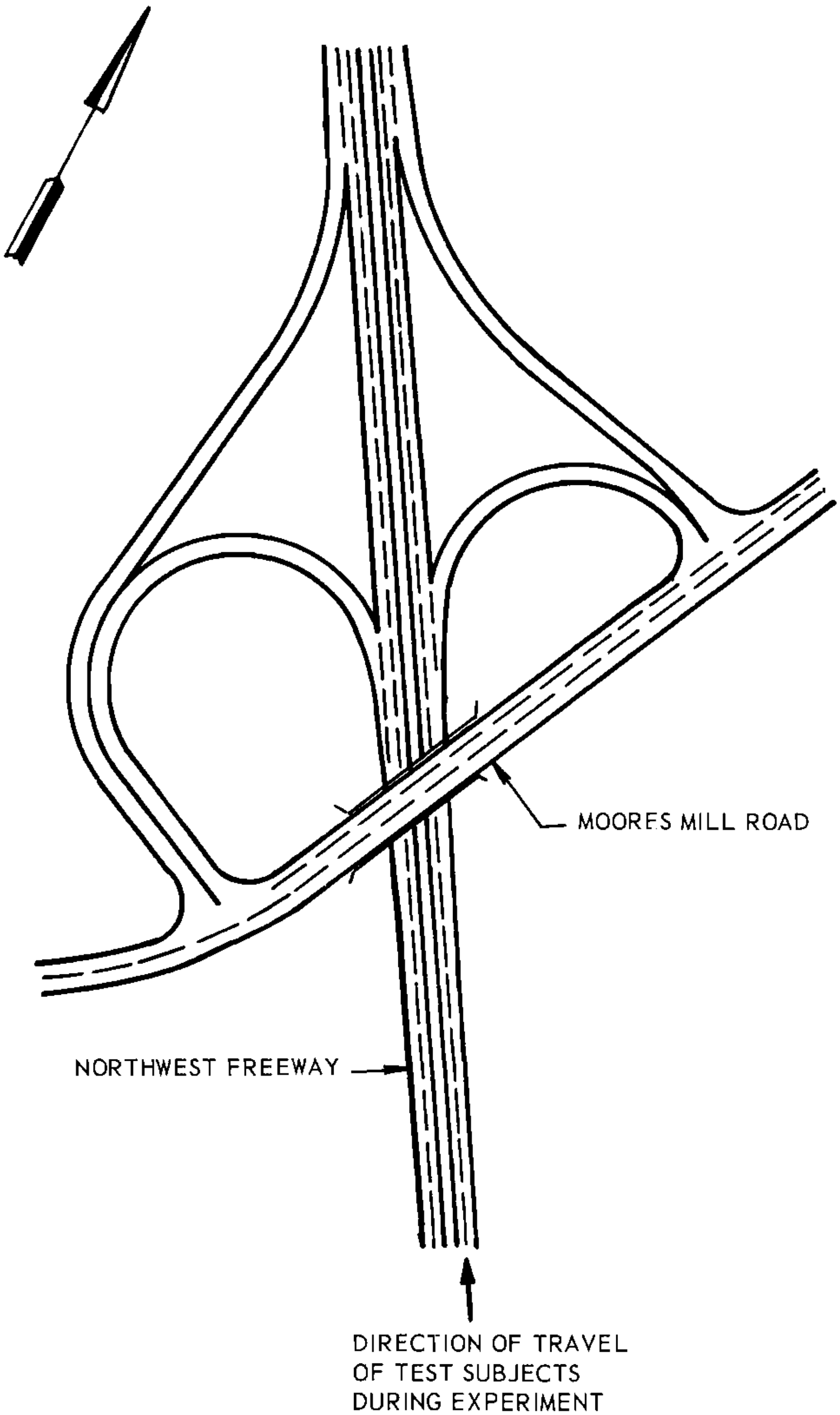

Figure 2. General Configuration of the Moores Mill Road Interchange.

within the limits of the study area, two of which, Northside Drive and Moores Mill Road, are modifications of the standard clover-leaf type, and the third at Howell Mill Road is of the diamond type design. The exit terminal selected for the purpose of the primary experiment was located at the Moores Mill Road interchange. The general configuration of this interchange is shown in Figure 2.

The Northwest freeway in the study area was designed in 1952 and as a result certain geometric features of the facility are below the present day urban freeway design standards. These differences in geometrics consist essentially of shoulder widths and type, median width and curb type, and the lengths and configuration of the exit ramps. Thus the two 12-feet wide concrete travel lanes provided in each direction on the freeway in the test section are separated by a 15-feet wide, raised, turf median, whereas present design standards recommend a minimum width of 20 feet for raised medians. Similarly, present standards recommend a mountable curb, along the raised median, set back from the edge of the travel lane to provide a four-feet wide offset or shoulder along the median. On the test section barrier type curbs are used with a two-feet gutter section between the face of the curb and the edge of the travel lane. The shoulders are of the turf type and of variable width, and did not meet present day design requirements of a minimum of ten-feet wide usable shoulder.

The differences between the exit terminal at the Moores Mill Road interchange and present design standards consists basically of differences in deceleration lane lengths and different points at which the curvature of the exit ramp begins. Present design standards

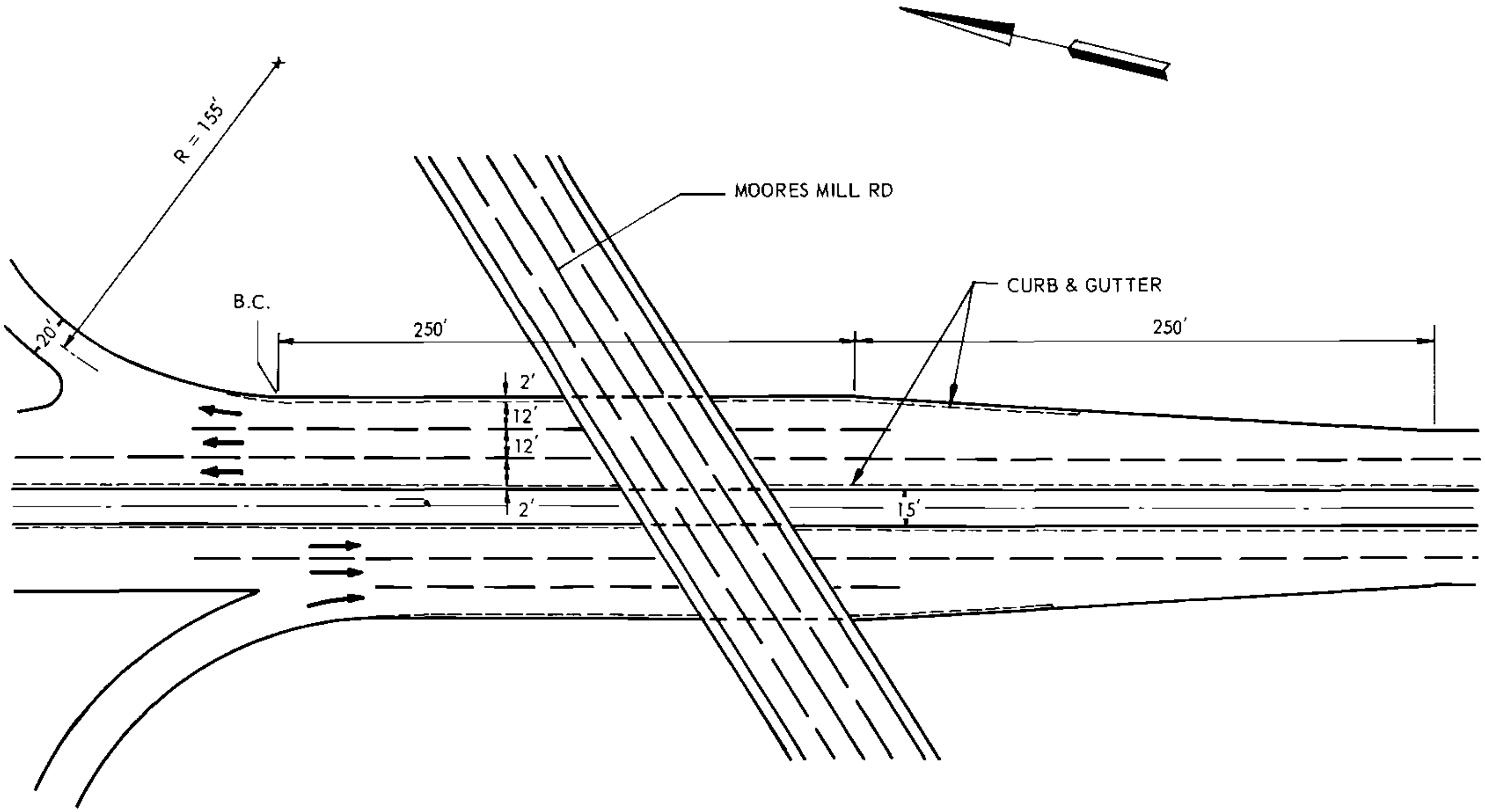

Figure 3. Layout of the Moores Mill Road Exit Terminal.

recommend full width deceleration lanes of 400 feet minimum lengths with a curvature in the deceleration lane, not exceeding 1°, to allow complete separation of the exit ramp from the through travel lanes before the beginning of the high degree of curvature of the exit ramp. The full length of the total deceleration section at the Moores Mill Road exit is 500 feet. Both the tapered section and the full 12-feet width deceleration lane measure 250 feet each. The curvature of the exit ramp, 155 feet centerline radius, commences at a point 100 feet in advance of the gore where the exit ramp separates from the through travel lanes. Details of the configuration of the deceleration lane and exit ramp are shown in Figure 3.

A dark pigment in the concrete pavement of the deceleration lane and tapered section provides a visual contrast between the latter and the through travel lanes. The gradient of the northbound lanes approaching the Moores Mill Road interchange is +3.5 per cent.

Traffic data on the Northwest Freeway obtained at a counting station south of Northside Drive showed an average daily total traffic volume of 47,350 vehicles, based on recent seven-day, 24-hour counts. The total average hourly traffic volume between 9 AM and 4 PM in the northbound lanes was 1,300 vehicles per hour.

Traffic volumes recorded on the exit ramp at Moores Mill Road during the conduct of the experiment showed an average hourly volume of 150 vehicles during the period from 9 AM to 4 PM.

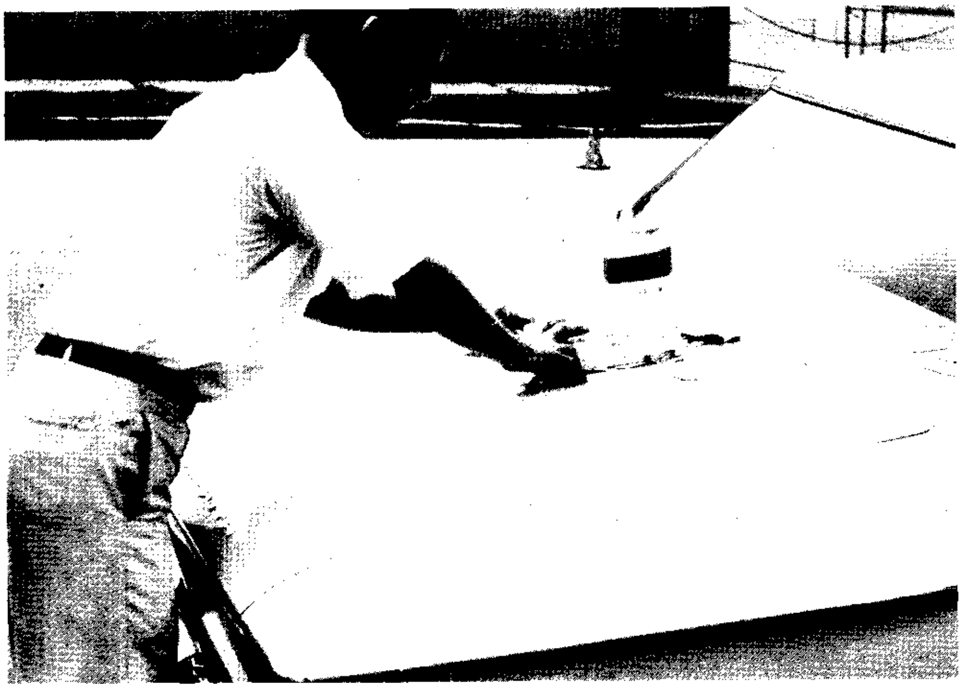

Figure 4. Hy-Com Receiver Mounted on Trunk Lid of an Automobile.

cation of proper recorder operation. In the transmitter the 12.1 KC carrier is amplitude modulated. Supression filters then remove the carrier and the lower sidebands and deliver the upper sidebands to the power output stage which energizes a loop antenna. The loop antenna establishes an inductive field which can be sensed by the receiver antenna as it passes the loop. To avoid confusion by having a southbound driver receiving a message intended for a northbound

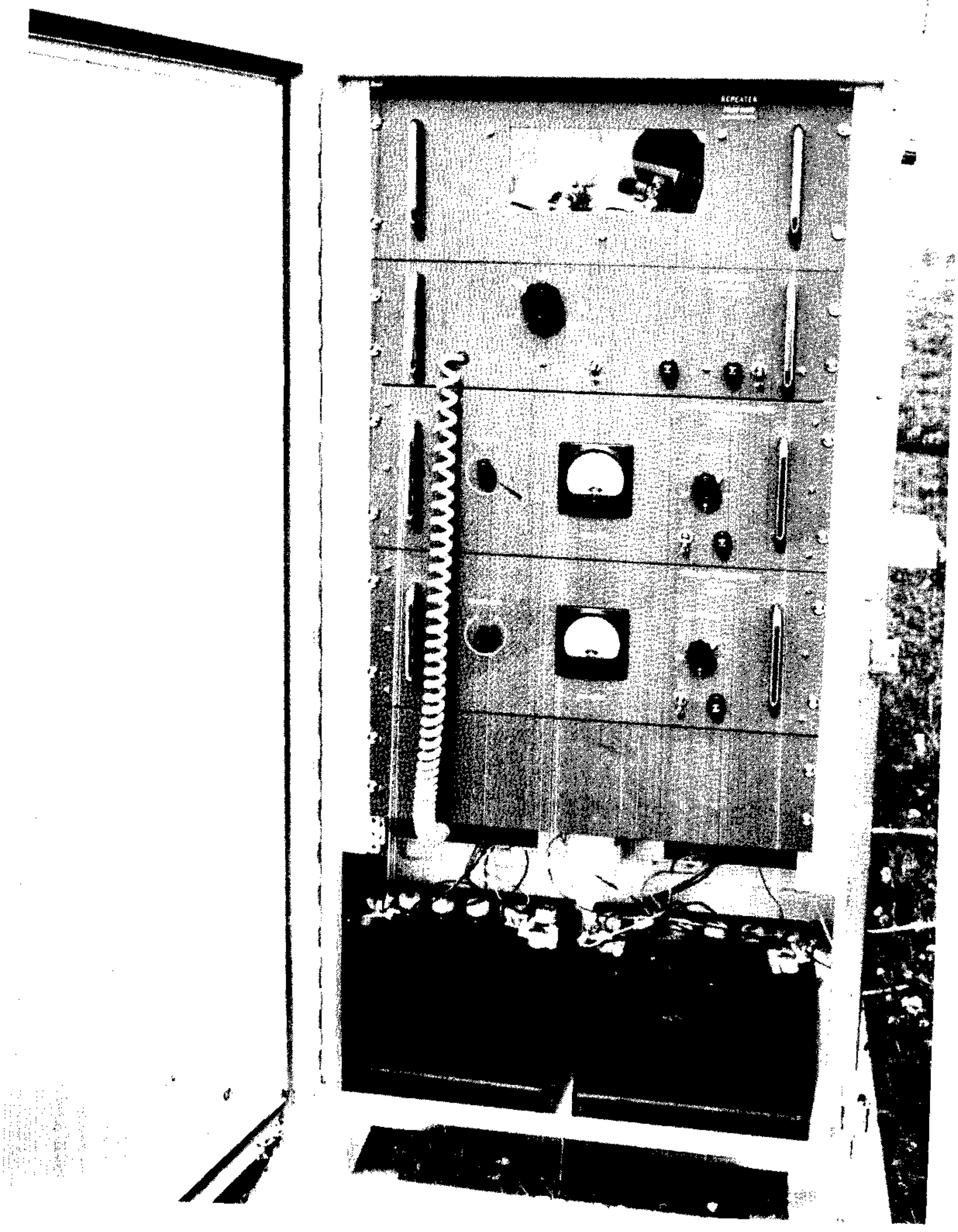

Figure 5. Inside View of Transmitter Cabinet.

Equipment and Instrumentation

Delco Radio "Hy-Com"

The system is designed to provide communications from the roadside to the driver and consists of a car mounted receiver and roadside transmitter. The receiver is encased in a plastic housing and has three circular magnets which hold the unit in place on the trunk lid of a car. A rubber-coated safety hook attached to the receiver is placed in the crack between the trunk lid and body of the automobile. The speaker is cable connected to the receiver and can be mounted on the sunvisor or inside body trim of the car with a spring clip. The receiving unit is powered by four 1-1/2 volt penlight batteries which provide for approximately 100 hours of continuous operation. Figure 4 shows a receiver mounted on the trunk lid of an automobile.

The transmitting system consists of a transmitter cabinet and two loop antennae which are placed on the shoulder. The transmitter cabinet is water tight and can be set up at any required point along the side of highway. The cabinet contains the message repeater and associated transmitting equipment and two 12-volt wet-cell batteries for a power supply. An inside view of the transmitter cabinet is shown in Figure 5.

The transmitter system is a single sideband, suppressed carrier, one-way communication link. Audio information to be transmitted is recorded on a magnetic drum in the repeater. The repeater records messages of any duration up to ten seconds and will automatically repeat them. A handset, located in the transmitter cabinet, serves as a microphone to permit recording and as a receiver to allow verifi-

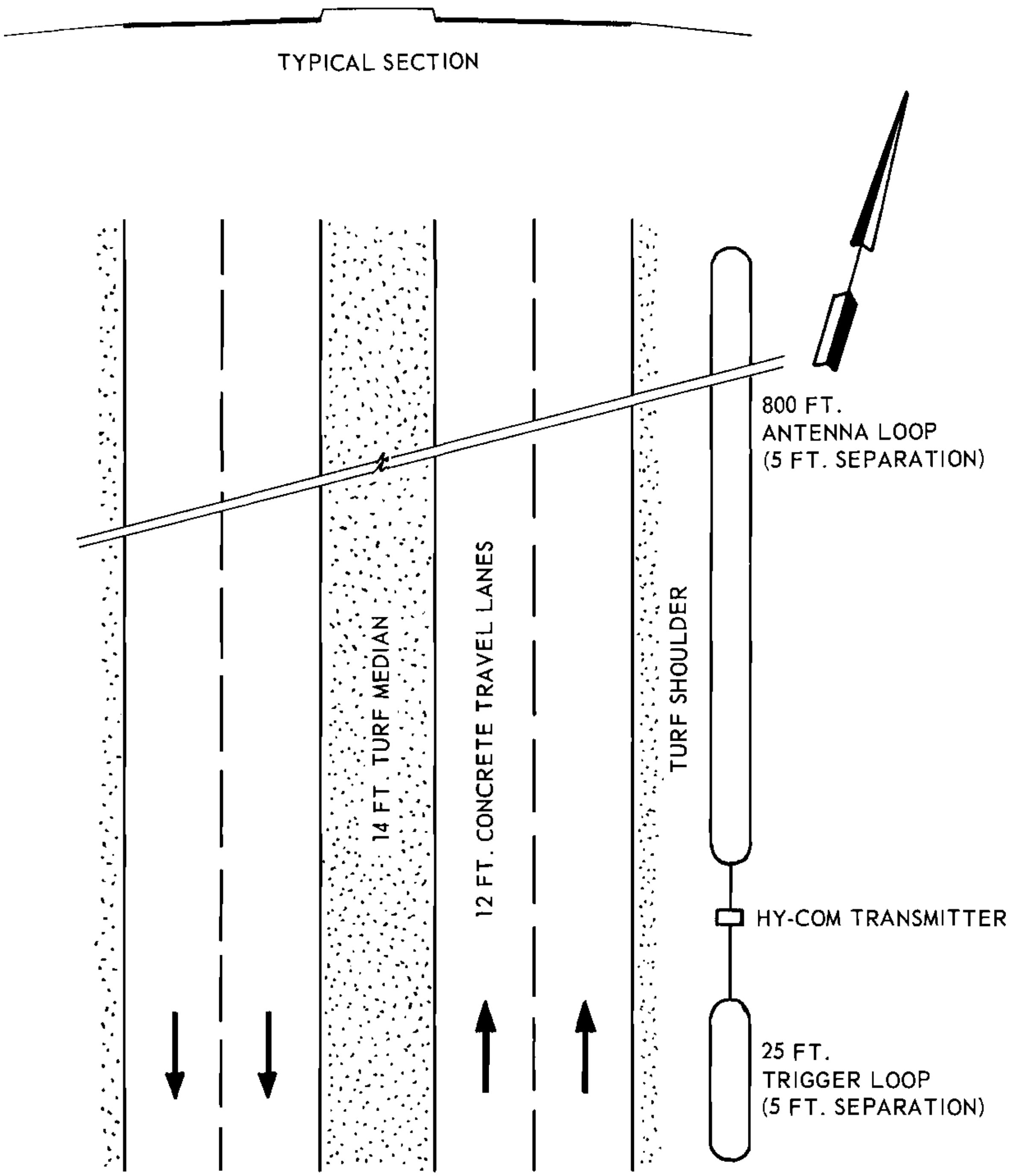

Figure 6. Typical Transmitter and Antenna Installation.

motorist, an additional trigger feature has been incorporated into the system. This feature consists of a 12.1 KC trigger transmitter and its associated trigger antenna. As the receiver mounted on the approaching automobile enters the induction field of the trigger loop antenna, which is positioned on the highway shoulder just in advance of the transmitter, a trigger circuit in the receiver is activated which energizes the audio stages of the receiver. A time delay holds the audio section in the "on" position to permit the automobile to reach the information antenna which is positioned just beyond the transmitter. As the receiver enters the field of the information antenna it senses the information signal and provides an audible message to the driver. Figure 6 shows a typical transmitter and antenna installation.

Traffic Analyzer

To collect data on vehicle speeds and placements at various locations along the deceleration lane and off-ramp at the Moores Mill Road interchange, the Bureau of Public Roads Traffic Analyzer was used.

The Traffic Analyzer is a mobile unit containing an assembly of equipment which provides automatic digital recording of speed and lateral placement data at several positions on a highway.[2] The equipment essentially consists of four adding machine recorders with specially designed solenoids mounted over the keys, a digital timer to indicate the time of day for each recording, and a speed timing device. The speed and placement detectors placed on the highway pavement are the usual two pneumatic tubes and a series of electrical contact strips, respectively. The sequence of operation is initiated by a vehicle actuating the first speed detector tube. This electrical contact starts

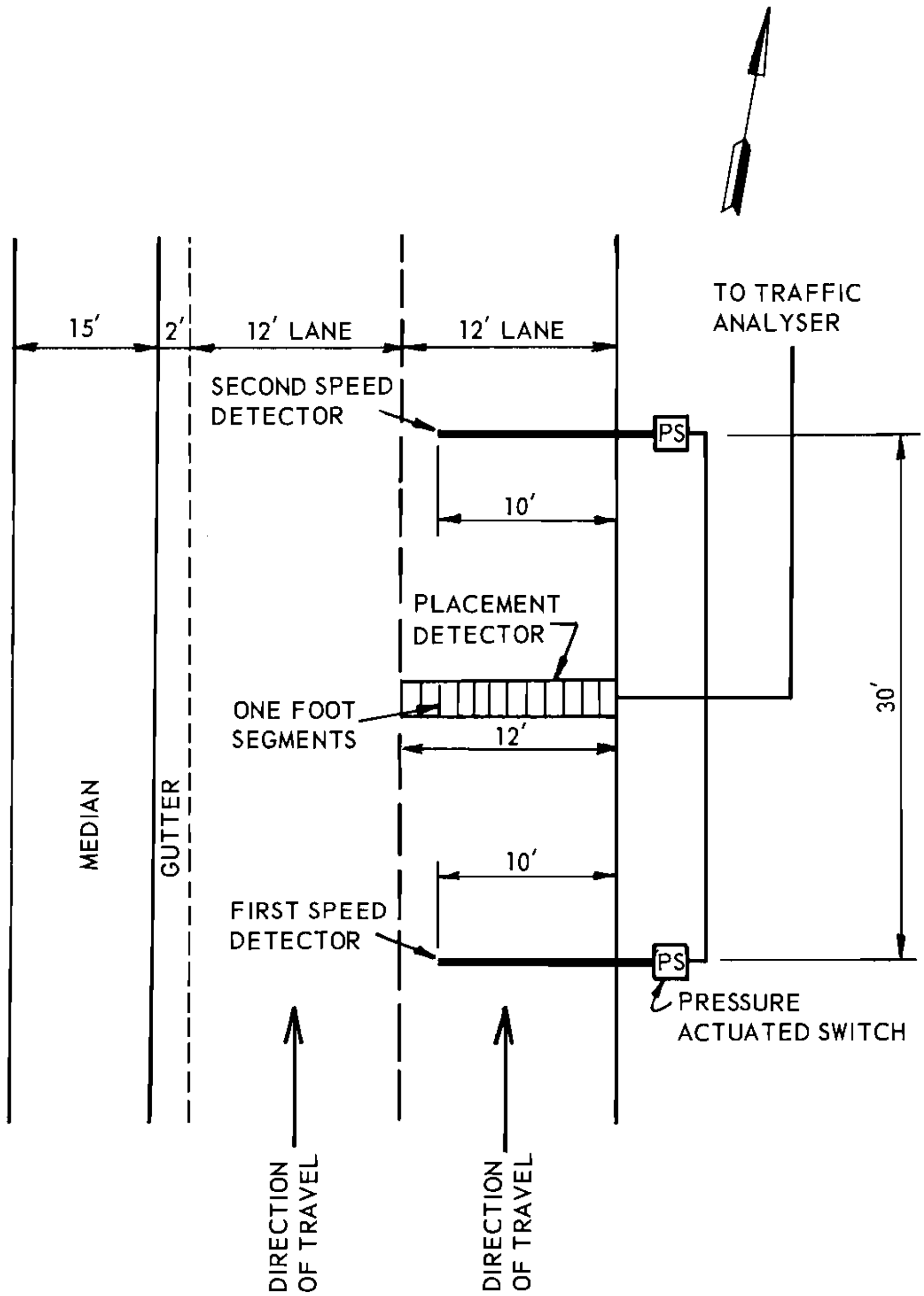

Figure 7. Typical Layout of Speed and Placement Detectors.

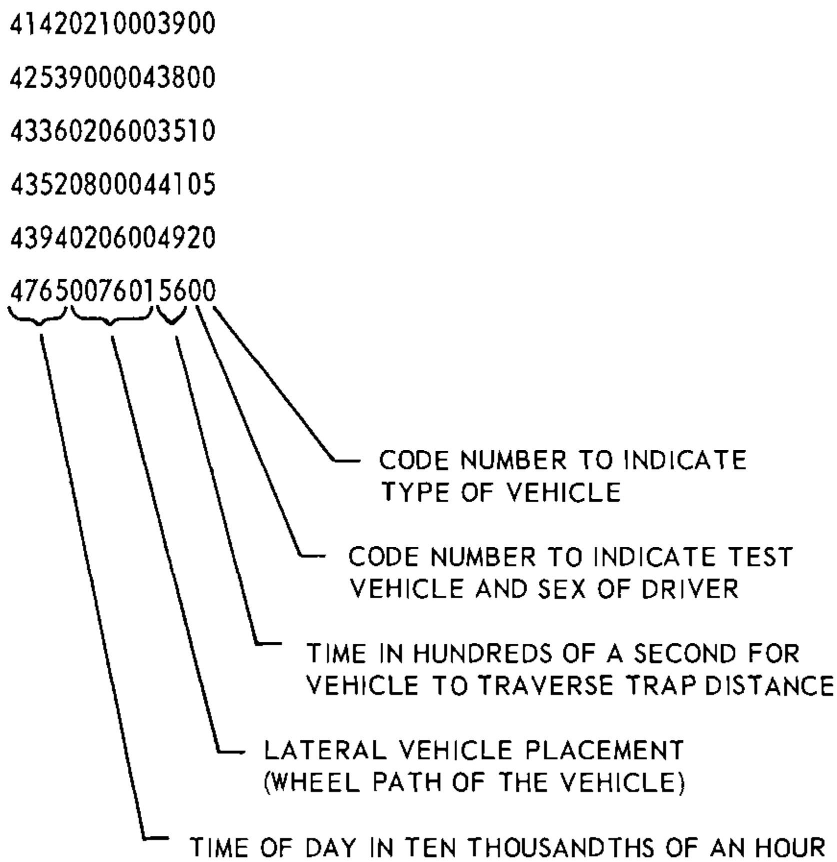

Figure 8. Typical Traffic Analyzer Printed Tape Output.

the speedmeter timer and activates the placement detector for that location. As the front wheels of the vehicle pass over the placement detector the appropriate solenoids are actuated and the information is immediately entered in the adding machine recorder. When the front wheels of the vehicle pass over the second tube of the speed detector, the speedmeter reading in units of one-hundredths of a second is entered on the recorder, the reading of the digital timer in ten-thousandths of an hour is transferred to the recorder, and a control signal causes the adding machine to print these data. A typical layout of speed and placement detectors is shown in Figure 7, and a section of a typical printed tape output is shown in Figure 8.

As indicated in the latter figure, the last two columns on the printed tape are used for vehicle type coding purposes. This coding of vehicle types is performed manually and requires an operator at each recorder to observe and classify each vehicle, and depress the appropriate code digit.

Camera Equipment

Time-lapse motion photography was used to collect information on vehicle operating characteristics at three positions along the test section. The camera equipment used for this purpose were Bolex 16mm movie cameras driven by 110-volt AC synchronous motors at a rate of 100 frames per minute. The function of the synchronous motor drive at each camera was to provide a constant and accurate rate of film exposure. Power was provided either by employing 12-volt heavy-duty batteries and vibrator-type converters, or from overhead street service lines where feasible.

Figure 9 (a). Advance Information Sign.

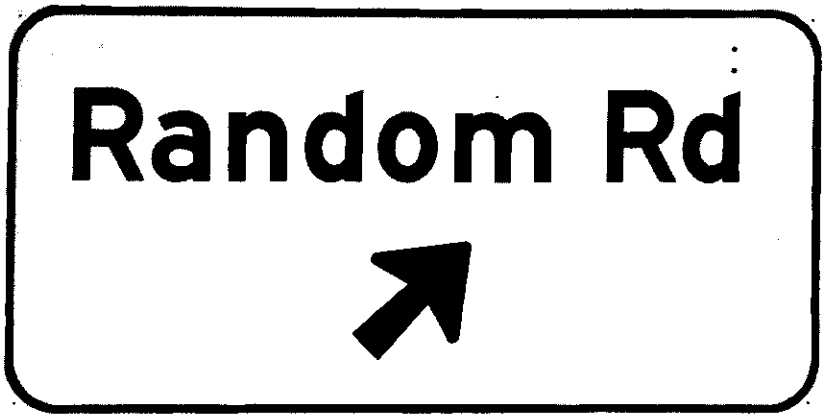

Figure 9 (b). Exit Direction Sign.

Figure 9 (c). Core Sign.

The camera shutter speed used was 1/15 of a second. Kodachrome II color film was used to allow identification of the test vehicles which were provided with bright red bumper stickers.

Highway Signs

To negate as much as possible the test subjects' specific advance knowledge regarding the exact location and characteristics of the freeway exit at Moores Mill Road, this interchange was renamed "Random Road" for purposes of the experiment.

Highway information signs, approaching within practical limits freeway signing standards were constructed of 3/4-inch plywood. The advance guide sign and the exit direction sign were eight feet by four feet, and the gore sign was five feet by four feet. To avoid undue interference with, and confusion to normal traffic, these signs consisted of a black legend on a white background as opposed to the standard white legend on a green background. The standard freeway signs carrying the Moores Mill Road legends were left unaltered during the conduct of the experiment. The "Random Road" signs were erected in each instance in advance of the standard freeway signs. The gore sign used in the experiment was placed directly over, and entirely obscured the standard freeway gore sign. Photographs of the three highway signs used in the experiment are shown in Figure 9.

The eight by four feet signs were mounted on two four-inch square wooden posts. A one-inch wide steel channel was affixed transverse to the posts to hold the bottom of the sign. Two bolts anchored the top of of the sign to the posts and provided a sturdy mounting. This type of mounting allowed rapid altering of the test conditions, i.e., the amount of guidance information provided, since erection or demounting of any one sign could be accomplished in a matter of minutes.

Citizen Band Radio

The area from which the test subjects were dispatched, the traffic analyzer, the three camera positions and three mobile patrol units were linked together with several Citizen Band and U.H.F. radio units. These channels of communication between project personnel at the various locations provided a high degree of coordination and efficiency in the general performance of the experiment.

Procedure of the Study

The experiment consisted of two major parts. The primary experiment was devoted to the evaluation of radio communications as an effective aid to the motorist in performing a diverging maneuver from a freeway traffic stream. A secondary experiment, conducted concurrently with the primary, performed a dual function. First, it was to provide an evaluation of the effectiveness of roadside radio communication as a general informational device in an urban environment. Second, it was to provide a "screen" for concealing from the participating test subjects the importance of the primary experiment. Thus, the provision of radio messages and simulated roadside activities on the test section in advance of the location where the diverging maneuver was to take place, was estimated to create adequate diversion of emphasis on the part of the test subjects to result in a more normal driving performance during the exit maneuver. Figure 10 shows the limits of the test sections of the primary and secondary experiments and the location of the staging area from which point the test subjects departed for each trip.

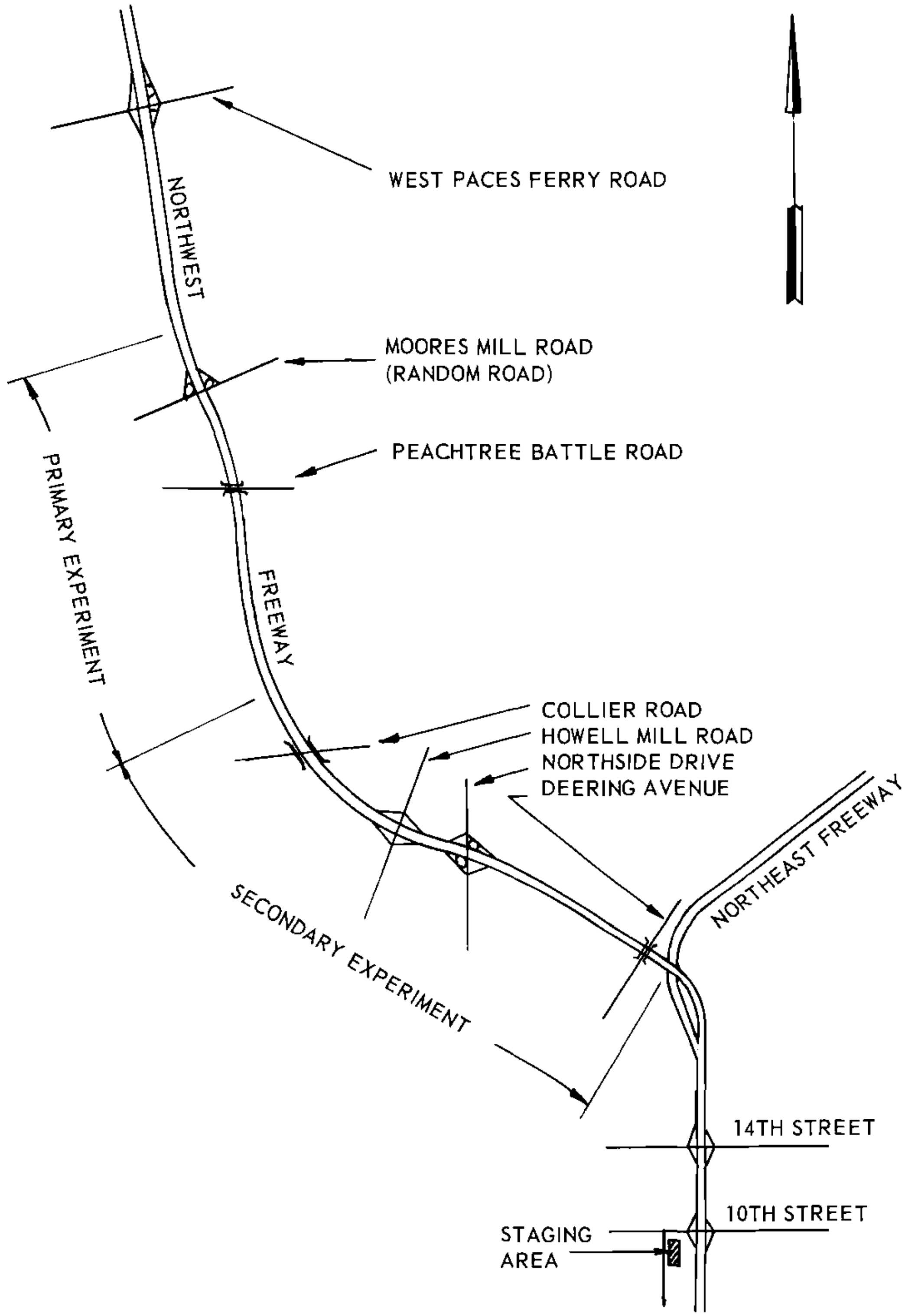

Figure 10. Test Route Showing Limits of Primary and Secondary Experiments.

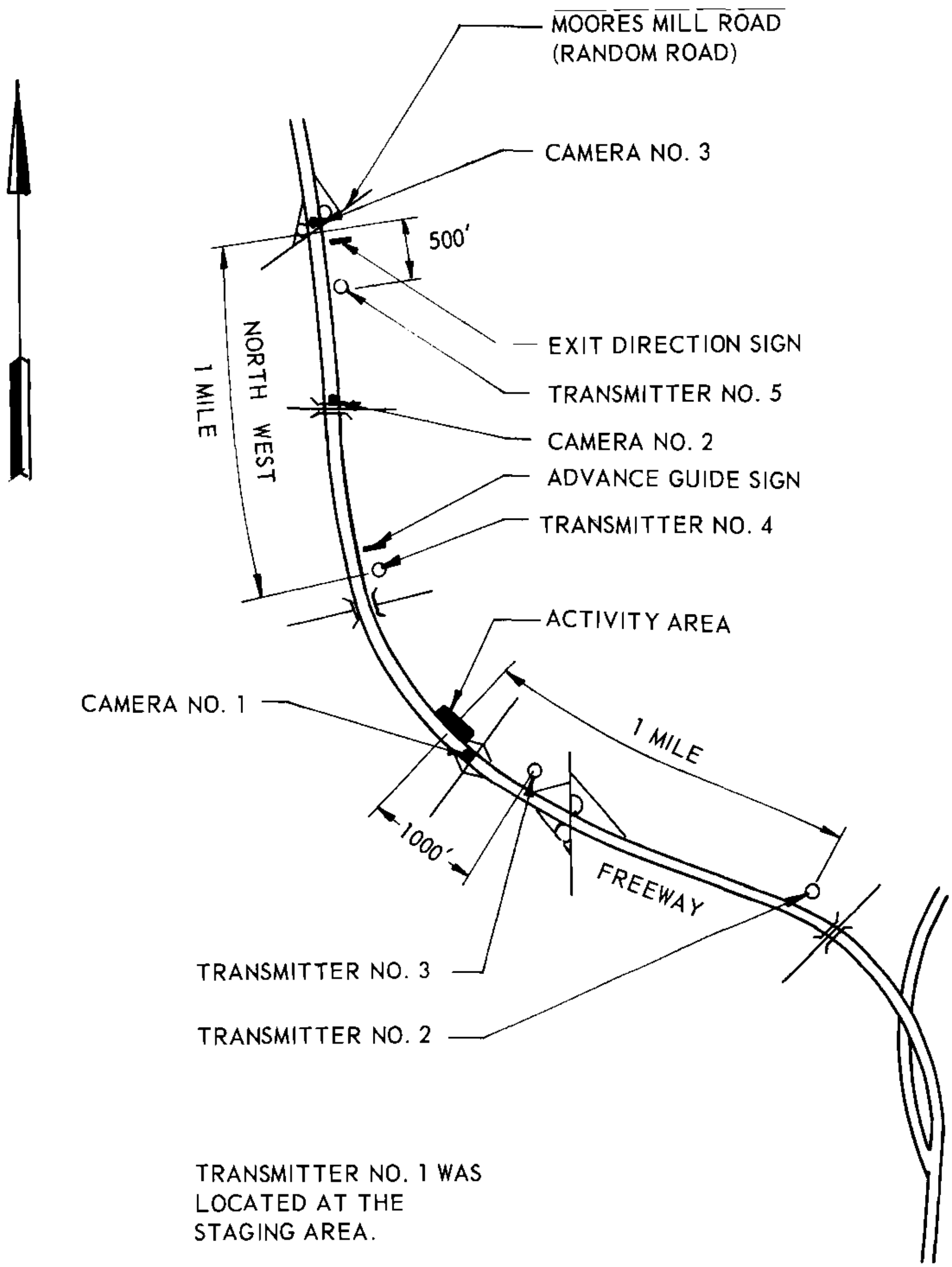

Figure 11. Transmitter, Camera, and Sign Locations Along the Test Section.

Primary Experiment

The primary experiment consisted of five separate tests, with each test repeated three times. The differences among the five tests consisted of varying degrees of advance and exit information provided and the use of different modes or combinations of modes of conveying this information. The conditions employed during the five tests are listed in Table 1. In this tabulation, visual information refers to the use of highway signing and audio information refers to the use of roadside radio communication. The advance information was provided at a distance of approximately one mile in advance of the Moores Mill Road (Random Road) exit. The visual exit information was provided near the beginning of the tapered section of the deceleration lane and at the gore. The transmitter and 800-feet long information antenna near the exit provided audio exit information in this area from a point 400 feet in advance of the deceleration lane to within 100 feet of the beginning of the exit ramp. The locations of the transmitters and highway signs are shown in Figure 11.

Secondary Experiment

The secondary experiment consisted of providing audio roadside messages regarding simulated roadside activities on the test section. Three different test conditions were used in the experiment: grass cutting on the highway shoulder, the positioning of a disabled vehicle on the shoulder adjacent to the outside travel lane, and the provision of general route information without any simulated physical roadside activity.

Table 1. Test Conditions Employed in the Primary Experiment

Test Number	Test Condition
1	Visual Advance Information No Exit Information
2	Visual and Audio Advance Information No Exit Information
3	Visual and Audio Advance Information Visual and Audio Exit Information
4	Visual Advance Information Visual Exit Information
5	Visual and Audio Advance Information Audio Exit Information

The actual messages broadcast to the test drivers during each of the five test conditions were as follows:

Test Number	Transmitter Number	Message
1	4	No Message
	5	No Message
2	4	"Random Road One Mile Ahead"
	5	No Message
3	4	"Random Road One Mile Ahead"
	5	"Random Road Exit"
4	4	No Message
	5	No Message
5	4	"Random Road One Mile Ahead"
	5	"Random Road Exit"

For the grass cutting experiment the City of Atlanta supplied a tractor-mower and operator to provide the mowing activity on the turf shoulder in the activity area. During this test, the only warning the motorists received regarding this roadside maintenance operation, other than radio messages, was provided by the tractor which operated with the headlights turned on. A photograph of the grass cutting activity is shown in Figure 12(a). The radio messages broadcast during this test were as follows:

Transmitter No. 2:	"Grass Cutting One Mile Ahead"
Transmitter No. 3:	"Caution, Grass Cutting 1,000 Feet Ahead"

In the experiment involving the disabled vehicle, a 1/2-ton pick-up truck with the hood raised was parked on the shoulder of the highway near the pavement edge. In this test no other warning devices other than the radio messages were employed. The radio messages provided in this test were as follows:

Transmitter No. 2:	"Disabled Vehicle One Mile Ahead"
Transmitter No. 3:	"Caution, Disabled Vehicle on Shoulder"

A photograph of the disabled vehicle scene is shown in Figure 12(b).

The general route information test was conducted without any simulated physical roadside activity and involved the provision of the following radio messages:

Transmitter No. 2:	"You Are Leaving Atlanta, Capital of Georgia"
Transmitter No. 3:	"Marietta 12 Miles. Chattanooga 115 Miles"

Test Subjects

The technique of selecting participants in the experiments by sampling from the general motoring public at a point along the highway was discarded in favor of pre-selecting volunteer participants. The latter procedure simplified site selection and allowed more positive control in scheduling the repeat participation of the test subjects necessary to evaluate the effect of radio communication on the learning process of the motorists.

Two days prior to the commencement of the experiment, the volunteer test subjects were asked to attend a briefing session. At this briefing, sufficient information was imparted to familiarize the test subjects with the operation and characteristics of the radio equipment and specific directions were given regarding the test route. The test subjects were randomly assigned to one of five groups. Each group was requested to travel over the test section on the Northwest freeway three times, each trip taking place on a different day. The test condition on each of these three trips was the same, but the test subjects were not informed of this situation prior to their participation in the test. The test subjects in group 1 participated only in test 1, group 2 in test 2, etc.

To prevent specific advance orientation on the part of the test subjects regarding the location of the designated point of exit from the freeway, Moores Mill Road was renamed "Random Road" for purposes of the experiment. The participants were requested to exit the freeway at "Random Road," the specific location of which was not revealed prior to the conduct of the experiments.

The avoid the influence of peak hour traffic volumes on the experiment, and the inconvenience to the test subjects resulting from peak hour traffic conditions, the tests were conducted between the hours of 9:30 AM and 3:30 PM. This six-hour period was divided into morning and afternoon periods, from 9:30 AM to 12:30 PM and from 12:30 PM to 3:30 PM, respectively. Each three-hour morning or afternoon period constituted a test period during which one of the group of test subjects executed one trip over the test route. To complete the five tests and three group trips per test, 15 periods or 7-1/2 days of experiments were required. The chronological order in which the tests were conducted was randomized. The schedule of the tests is shown in Table 2.

The test conditions of the secondary experiment were arranged chronologically to fit the time schedule established for the primary experiment, and in a manner to ensure that the entire number of test subjects participated once in each of the three test conditions. The schedule of the test conditions for the secondary experiment is included in Table 11.

In view of the limitations in the number of volunteer test subjects available, it was necessary to consider the selection of a control group from the general motoring public. The hypothesis that the driving behavior of a special control group of motorists fully cognizant of the experiment, would not differ from that of non-participating motorists, was investigated utilizing data obtained on the Kentucky Toll Road, during research conducted in 1963, where a special control group of drivers was established.[1] An analysis of three random samples of these

Figure 12 (a). Grass Cutting Activity.

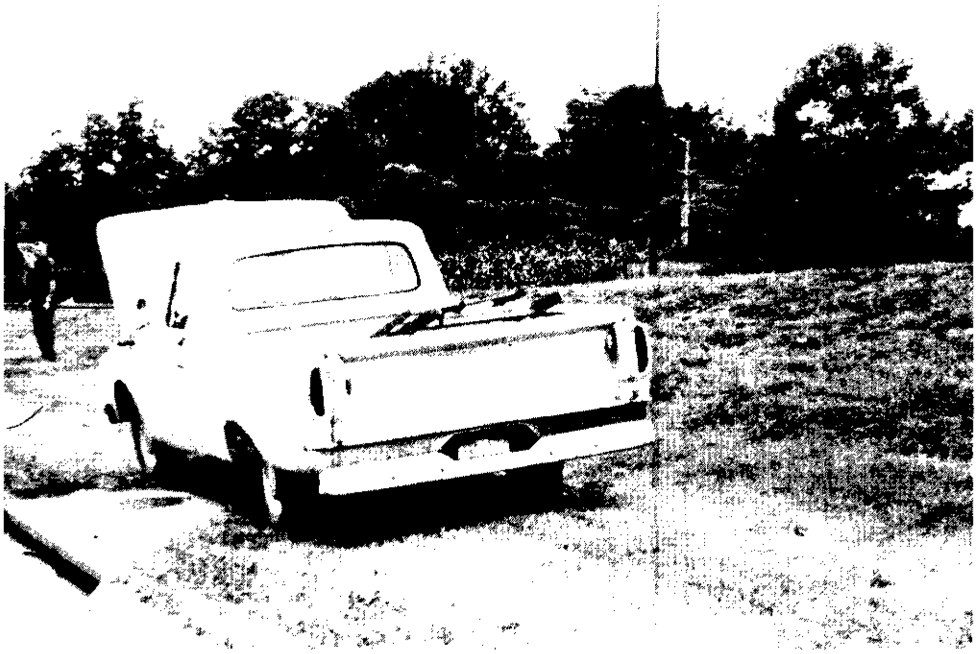

Figure 12 (b). Disabled Vehicle.

Table 2. Schedule of Tests

Date Period	Test and Group No.	Primary Experiment Trip No.	Secondary Experiment Test Condition
July 21 A.M.	1	1	Disabled Vehicle
July 21 P.M.	4	1	Disabled Vehicle
July 22 A.M.	1	2	Grass Cutting
July 22 P.M.	5	1	Grass Cutting
July 23 A.M.	3	1	Disabled Vehicle
July 23 P.M.	2	1	Disabled Vehicle
July 24 A.M.	3	2	Route Information
July 24 P.M.	4	2	Grass Cutting
July 27 A.M.	2	2	Grass Cutting
July 27 P.M.	3	3	Grass Cutting
July 28 A.M.	1	3	Route Information
July 28 P.M.	5	2	Route Information
July 29 A.M.	4	3	Route Information
July 29 P.M.	2	3	Route Information
July 30 A.M.	5	3	Disabled Vehicle

data revealed no significant difference in the speeds of the control group and non-participating motorists. Therefore, the control group data obtained in the current experiments were based on the observations of randomly selected motorists not associated with the experiment.

Conduct of the Experiment

The experiments were conducted during the period from July 21 to July 30, 1964.

On the designated day and within the limits of the stipulated three-hour period, the volunteer participants in the appropriate test group arrived at the staging area, where project personnel installed the Hy-Com receivers and speakers on the vehicles of the test subjects. Colored adhesive stickers were applied to the bumpers of the test vehicles at this point to allow easy identification of the test vehicles during the film analysis and to provide ready identification for the traffic analyzer operators where manual coding was required.

Transmitter No. 1 located at the staging area provided a final test for adequacy of performance of the receiver and speaker subsequent to their installations on the test vehicle. Driving instructions and directions for travel over the test section which the test subjects received during the briefing session were briefly reiterated for each driver just prior to his departure from the staging area. The test driver then proceeded along the designated route to the test section on the Northwest Freeway where audio and visual messages were given in accordance with the test schedule shown in Table 2.

. Approximately 1,000 feet beyond the location of transmitter No. 3, camera No. 1 was positioned on the overhead structure of Howell Mill

Road and recorded the passage of the test vehicles. This camera position was the only data observation station for the secondary experiment. Two 100-foot reels of film, each providing 40 minutes of continuous filming, were used at this camera location during each three-hour test period. The film was exposed continuously during the following time periods: from 9:30 A.M. to 10:10 A.M. and from 10:30 A.M. to 11:10 A.M. during the morning tests, and from 12:30 P.M. to 1:10 P.M. and from 1:30 P.M. to 2:10 P.M. during the afternoon tests. A total of 29 100-foot reels of film were used in the secondary experiment.

At approximately 0.4 miles in advance of the Random Road exit, camera No. 2 was located on the overhead structure of Peachtree Battle Avenue. At this point the test subject had already received the advance exit information. Data collection at camera No. 2 was based on the same rate and time schedule of film exposure as at camera No. 2. Thus, two 100-foot reels of film were used also at this position during each three-hour test period.

Camera No. 3 was located on the overhead structure of Moores Mill Road (Random Road) and recorded vehicle travel characteristics along the tapered section of the deceleration lane. In addition, four traffic analyzer data collection positions were located in the vicinity of the exit. The traffic analyzer trap locations are shown in Figure 14 (page 35). Data collection at these positions near the exit was on a continuous basis. The traffic analyzer traps recorded data on all vehicles exiting the freeway at Moores Mill Road (Random Road), and the time-lapse movie photography was interrupted only to allow reloading the camera at the end of each film. Reloading the camera required approximately ten minutes. A total of 84 100-foot reels of film were exposed during the conduct of the primary experiment, 29 reels at camera No. 2 and 55 reels at camera No. 3.

Because the speed and placement traps of the traffic analyzer in the vicinity of the exit covered only one lane width at any one position, it was possible for a vehicle to by-pass the first three traps and still exit via the Moores Mill Road (Random Road) off-ramp. Thus a vehicle approaching the interchange in the inside or median lane could by-pass the first speed and placement trap. Then depending on the angle at which the vehicle veered across the other lane to the deceleration lane and exit it could by-pass the second and conceivably the third traffic analyzer traps. Those test vehicles failing to exit at Moores Mill Road could conceivably miss all four of the traffic analyzer traps.

Test vehicles missing some of the traps, and the passage of test vehicles through the camera observation areas during periods of reloading or down time, produced an unequal number of data observations at the various points along the test section. In addition, the number of test subjects actually participating differed between groups, and differed between trips of any one group. The number of data observations made in each of the three trips for each of the five tests, and the number of test vehicles by-passing the placement traps are shown in Appendix A.

Data Reduction

Film Analysis

The film exposed at the three camera locations was analyzed with

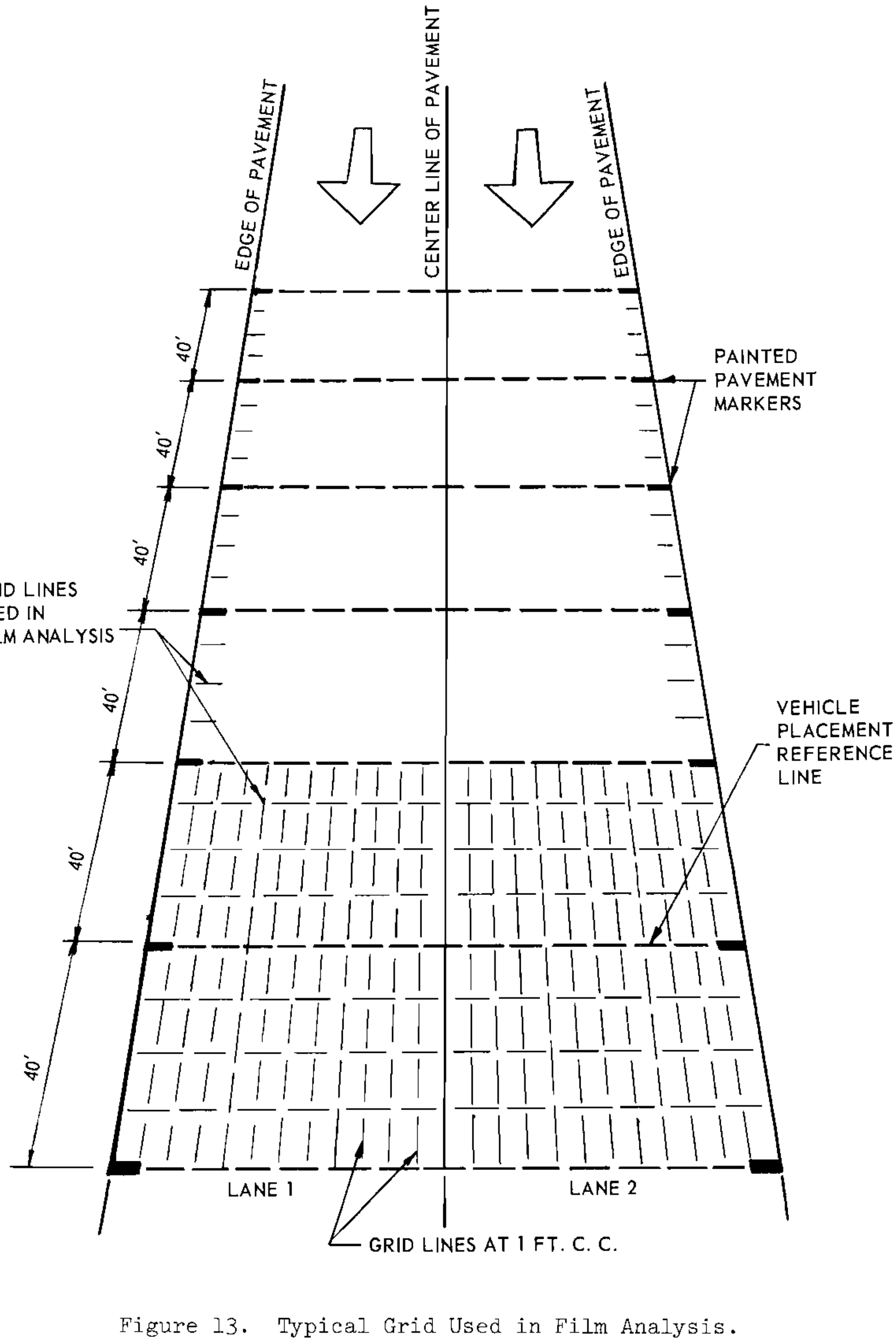

Figure 13. Typical Grid Used in Film Analysis.

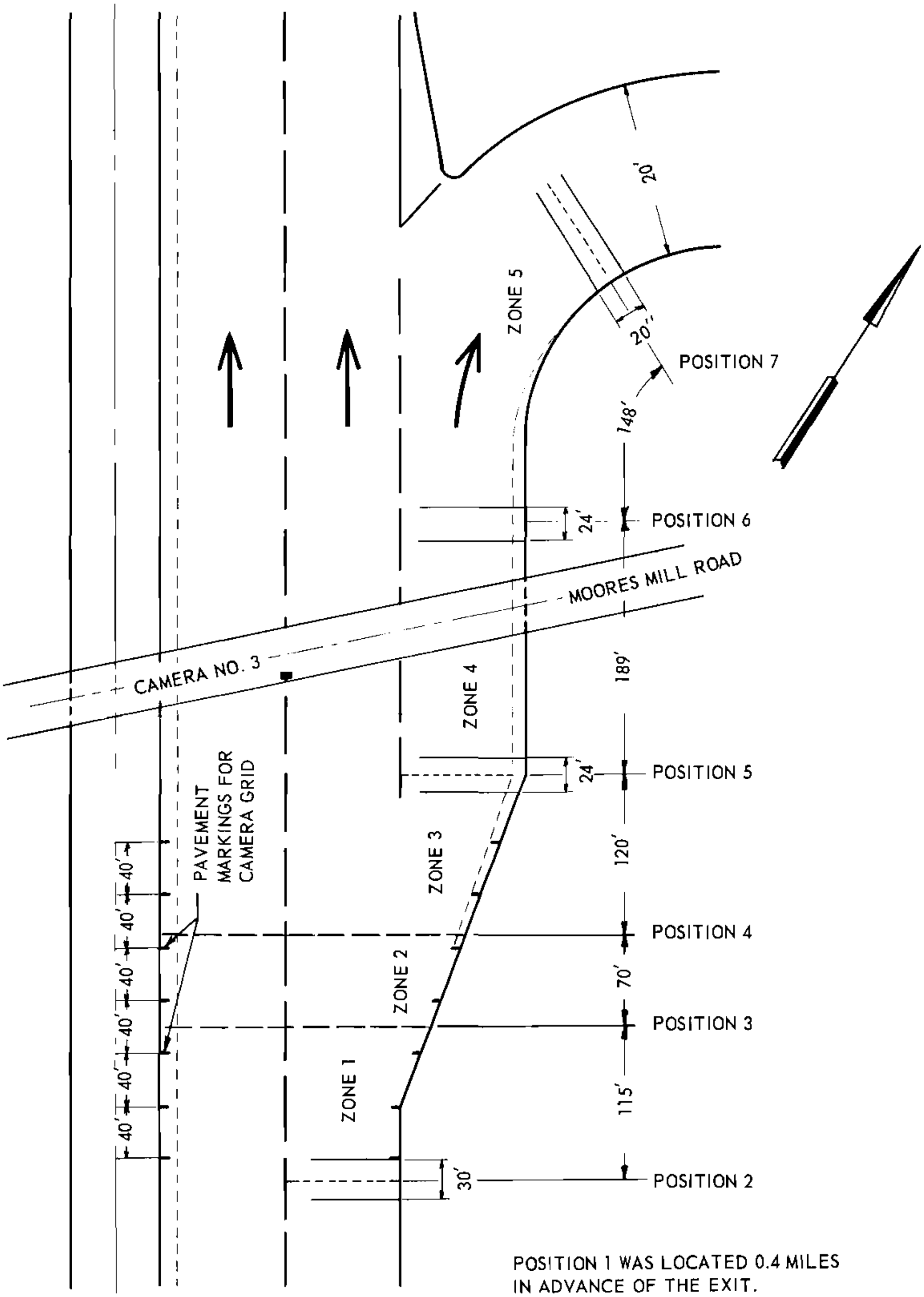

Figure 14. Locations of Data Observation Points in the Vicinity of the Exit.

the use of time and motion projector which allowed a frame by frame projection of each roll of film.[3] The technique of speed determinations and lateral positions of the vehicles is briefly summarized here.

At the camera observation points, markings were painted on the highway pavement edges at 40-foot intervals for a total distance of 240 feet. With the aid of these markings a grid was superimposed on a screen on which the film was being projected. With a constant and known time interval between successive film frames and with the distance between successive locations of a vehicle obtainable from the superimposed grid, vehicle speeds were determined for all test and control vehicles. A typical grid used in the film analysis is shown in Figure 13.

The lateral position of each vehicle was noted near the reference line in the foreground of the grid. These vehicle placements readings, indicating the lateral distance between the outside or shoulder edge of the pavement and the center of the vehicles, were obtained to the nearest half foot.

In the foregoing speed determinations readings were obtained at the vehicle position when it first entered the grid and at the last position before the vehicle left the grid. During the analysis of the film data obtained at camera location three an additional grid reading for each vehicle was obtained near the midpoint of the grid. This information allowed the computation of average vehicle speeds in the upper or first section of the grid and similarly for the lower or second section of the grid. The average value of each of the grid position readings, initial, middle and final, were computed using all the vehicles analyzed. The midpoints between these average grid locations were selected as the data observation positions, three and four, at which the vehicles observed were travelling at the determined average rate of speed. Locations of the data observation points in the vicinity of the exit are shown in Figure 14.

In addition to the grid location readings to determine the vehicle speeds at camera location three, lateral placement readings were obtained at each of the three vehicle positions in the grid. These lateral placements for each vehicle were referenced to position three and four by interpolation between two adjacent readings.

Traffic Analyzer--Data Analysis

The traffic analyzer data required the decoding of the printed tape data and the correlation or tracing of each vehicle through each of the four positions. Decoding the data yielded the speed of each vehicle and the lateral distance between the center of each vehicle and the pavement edge. Correlation of each set of vehicle data through the four traps was obtained by starting with the tape output of position seven, the exit ramp position, where the first test vehicle was located on the tape with the aid of the code number punched in the last column. Each test vehicle data entry thus found was correlated to entries of corresponding vehicles on the tapes of the other three traffic analyzer positions. This correlation was simplified considerably with the aid of the time of day which was recorded for each entry in the first four columns of the tape output.

At position two the vehicle data on the tape output of a representative sample of through traffic vehicles were decoded.

Rates of Deceleration

With the individual vehicle speeds ascertained at the various positions along the highway, the rates of deceleration between these positions along the deceleration lane and the off-ramp were computed.

Deceleration rates were computed for five zones. The location and extent of these zones is indicated in Figure 14, and in each instance consist of the longitudinal section of the highway between two consecutive speed measurement positions.

Because the decimal timer of the Traffic Analyzer and the time basis of the film intervals lacked sufficient accuracy, the deceleration rates for each vehicle were computed on the basis of initial velocity, final velocity and distance traversed using the following relationship:

$$\text{Deceleration} = \frac{V_2^2 - V_1^2}{2S}$$

where V_1 = initial velocity

V_2 = final velocity

S = distance traversed

The deceleration rate in the zone between positions 1 and 2 would have been of little or no analytical value because of the large distance between these positions and therefore no computations or analysis were carried out for this section.

CHAPTER III

ANALYSIS OF THE DATA

Analysis Technique

In view of the unequal number of test subject data obtained on each of the three trips for the five conditions, the standard analysis of variance technique was not applicable. The analysis of variance method used for the non-orthogonal data is described in detail in reference 4. A description of the analysis technique is summarized as follows:

An estimate of the common variance of each set of data was obtained by pooling the sum of squares within all the subclasses. Homogeneity of the data was then tested by calculating estimates of the variance of each factor separately and comparing them with the estimate of the common variance. If the hypothesis of homogeneity was rejected, the sum of squares between all classes was split into independent sums related to the fitting of constants by least squares and to an interaction term. This interaction term was then compared with the common variance to test for interaction between the factors.

Separate two-factor analyses between test conditions and trips were performed at each data observation position because of a lack of homoscedasticity of the data between positions. This approach also avoided complicities in the results due to anticipated test-position and trip-position interactions.

Subsequent to the analysis of variance and for those positions where significant differences in the factors were indicated, a multiple comparison test was applied to identify those levels of any factor which were significantly different from other levels. Standard tests, such as Duncan's multiple range and Tukey's comparison were not applicable because of the unequal cell sizes. Therefore, Scheffe's method for multiple comparisons was used by contrasting the differences between all the possible combinations of two levels until the significant difference for the range of levels was determined.[5] In four instances Scheffe's procedure failed to detect the significant differences between levels and in these situations the unequal cell sizes were ignored and approximations obtained with Duncan's multiple range test.[6] All contrasts were determined at the 10 per cent significance level.

Results of the Data Analysis

Primary Experiment

Analysis of Variance--Vehicle Speeds. The analysis of variance of the test and control vehicle speeds at the seven data observation positions showed significant differences between tests at all positions except position No. 1. The data observation positions are shown in Figure 14. At position No. 7, on the exit ramp, the tests were significantly different at the 10 per cent level but not at the 5 per cent level. The trip factor was found to be non-significant at positions 1, 2, 3 and 4, and significant at positions 5, 6 and 7.

The analysis of variance results for the dependent variable "speed" is shown in Appendix B. At those positions where significant differences in vehicle speeds were found, comparison tests were made to determine which of the test groups and control group, and which of the trips were significantly different. Table 3 show the rank order and significant differences of vehicle speeds at the seven positions. Non-significant differences in vehicle speeds between the test and control groups is indicated by the underscoring in the above table. Thus at position one there is no significant difference between any of the test and control group vehicle speeds. At position two, however, test group one is significantly different from test group three and the control group. At this position, test groups 2, 4 and 5 are not significantly different from each other or from any of the other groups.

The results of the analysis at position one indicate that the various test groups and the control group operated their vehicles in a manner which did not produce significantly different speeds among the groups. Test group three was found to have significantly higher speeds than test group one throughout the length of the deceleration zone except at the beginning of the deceleration lane taper. The control group, similarly as test group three, exhibited significantly higher speeds than group one throughout the deceleration area, except at the end of the deceleration lane and on the off-ramp. At the end of the deceleration lane the control group speed was not significantly different from any of the other groups, and on the off-ramp its speed was significantly lower than the speed of group three. Test group four was found to have significantly higher speeds than test group one at the midpoint along the taper and at the end of the deleceration lane. Similarly, test group five showed significantly higher speeds than test group one at two locations along the deceleration section.

Mean vehicle speeds for each test group at the seven positions near the exit are shown in Figure 15.

Table 3. Rank Order and Significant Differences Between Test and Control Groups for the Independent Variable "Speed" (Significance Level 10 Per Cent)

Position	Lowest Speed					Highest Speed
1	Test 1	Test 4	Test 5	Test 2	Test 3	Control
2	Test 1	Test 2	Test 5	Test 4	Test 3	Control
3*	Test 1	Test 2	Test 4	Test 3	Test 5	Control
4	Test 1	Test 2	Test 5	Test 3	Test 4	Control
5	Test 1	Test 4	Test 2	Test 3	Test 5	Control
6	Test 1	Test 2	Control	Test 5	Test 4	Test 3
7*	Control	Test 4	Test 1	Test 2	Test 5	Test 3

There are no significant differences between those conditions underlined.

*The significant ranges for these positions were not detectable with Scheffe's procedure, and were estimated using Duncan's procedure assuming equal numbers of observations in the subclasses.

The results of the comparison tests between the three trips for the seven positions are summarized in Table 4. The vehicle speeds during the three trips were found to be not significantly different,

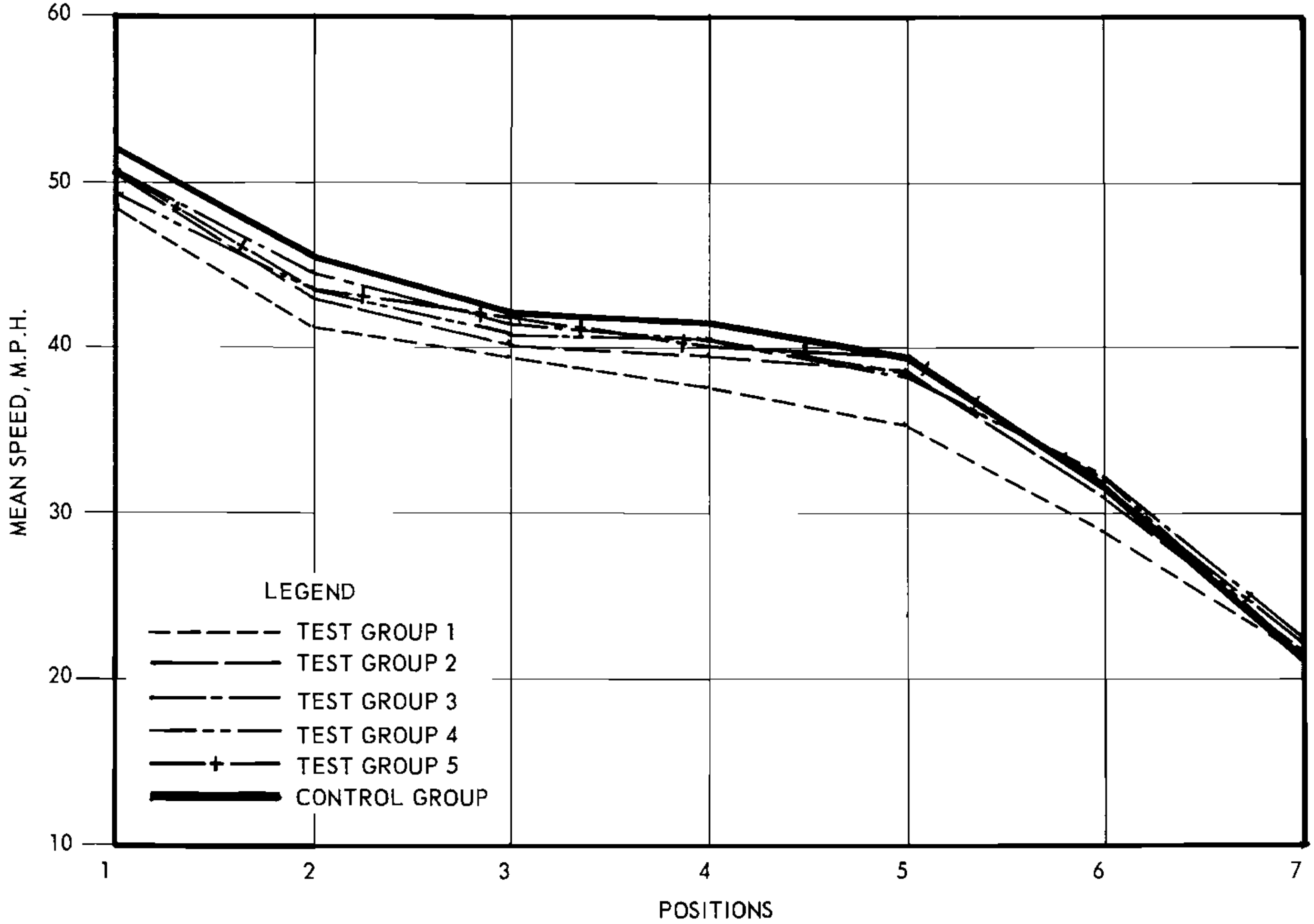

Figure 15. Mean Vehicle Speed of Each Test Group.

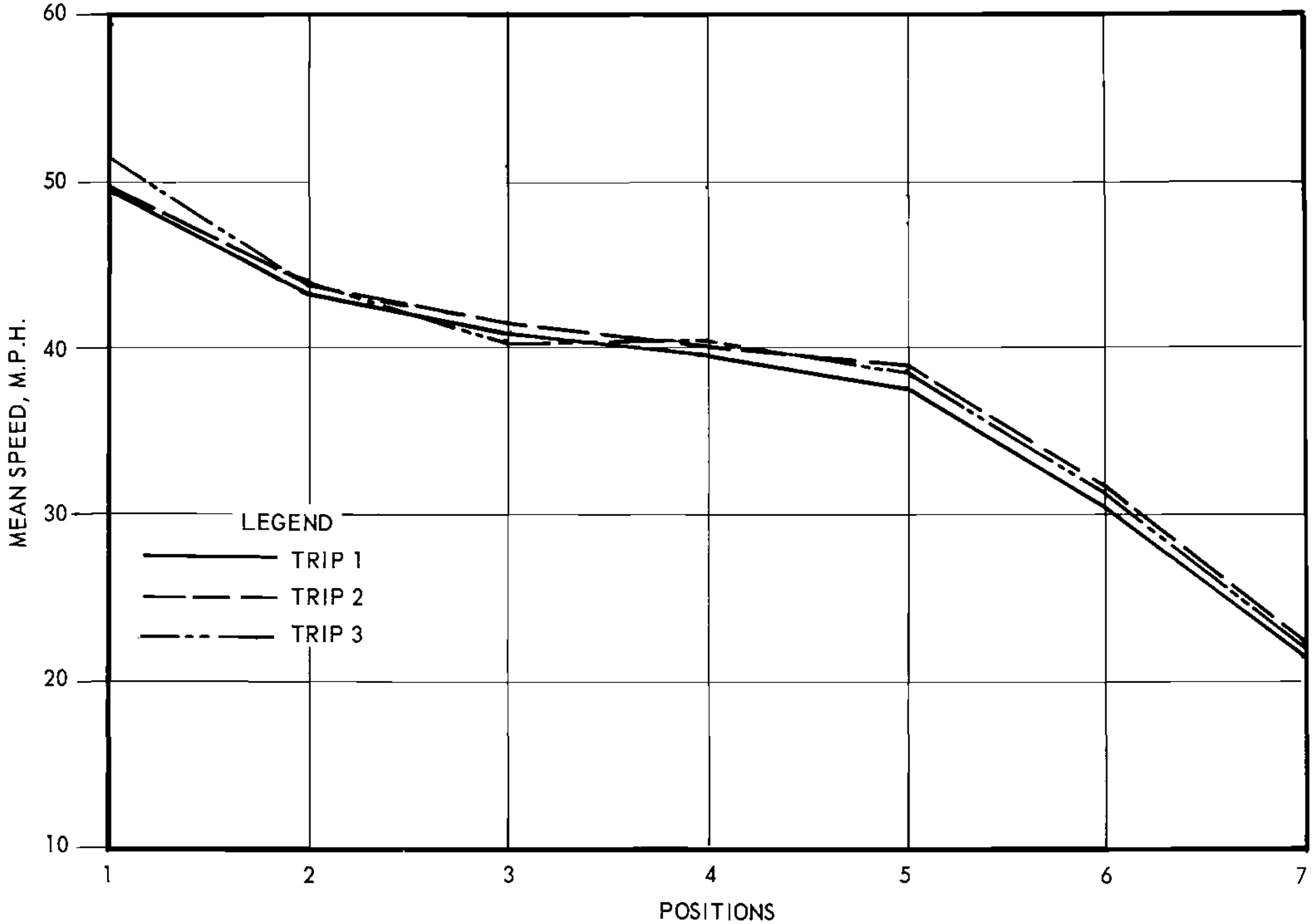

Figure 16. Mean Vehicle Speed During Each Trip.

at the approach to, and along the deceleration lane taper. However, from the beginning of the full-width deceleration lane through to the exit ramp the vehicle speeds during trip one were significantly lower than those during trip two.

Mean vehicle speeds for each trip at the seven positions are shown in Figure 16.

Analysis of Variance--Deceleration. Deceleration rates under the various test conditions and for the control group were found to be not significantly different at the 10 per cent level in zones 1 and 2, but significantly different deceleration rates were indicated in zones 3, 4, and 5. The locations of the observation zones are shown in Figure 14. The deceleration rates were found to be significantly different during the three trips in zones 1 and 2, and not significantly different in zones 3, 4, and 5. A summary of the results is shown in Appendix B.

The results of the comparison tests between deceleration rates for the test groups and the control group are tabulated in Table 5, and the comparison test results for the three trips are shown in Table 6.

Deceleration rates were found to be not significantly different among the test groups and the control group in the first two zones or along the first half of the tapered section of the deceleration lane. In zone three, the second half of the tapered deceleration section, the control group and test group one decelerated at a significantly greater rate than test group two. In zones 4 and 5, which is the length of the full width section of the deceleration lane and onto the exit ramp, the control group decelerated at a significantly greater rate than test group one. Mean vehicle deceleration rates for each of the groups of the five zones are shown in Figure 17.

Table 4. Rank Order and Significant Differences Between Trips For the Dependent Variable "Speed" (Significance Level 10 Per Cent)

Position	Lowest Speed		Highest Speed
1	Trip 1	Trip 2	Trip 3
2	Trip 1	Trip 3	Trip 2
3	Trip 3	Trip 1	Trip 2
4	Trip 1	Trip 2	Trip 3
5	Trip 1	Trip 3	Trip 2
6	Trip 1	Trip 3	Trip 2
7	Trip 1	Trip 3	Trip 2

There are no significant differences between those trips underlined.

Significant differences between deceleration rates during the three trips were found to exist in zones one and two. The rate of deceleration was lower during the first trip than during the second trip in zone one, and in zone two the rate during the first trip was significantly higher than during trip three. Mean vehicle deceleration rates for each trip in the five zones are shown in Figure 18.

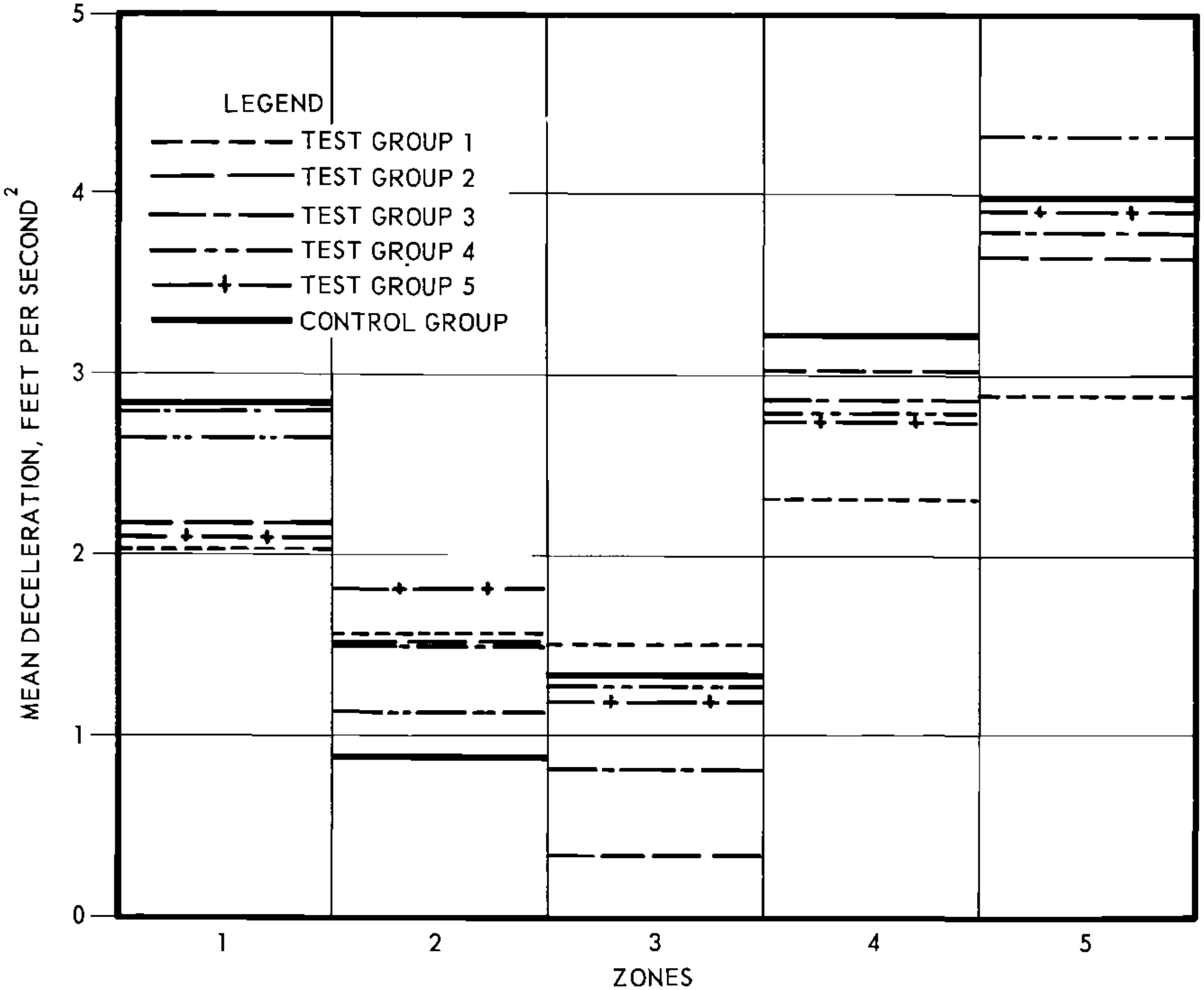

Figure 17. Mean Rate of Deceleration for Each Test Group.

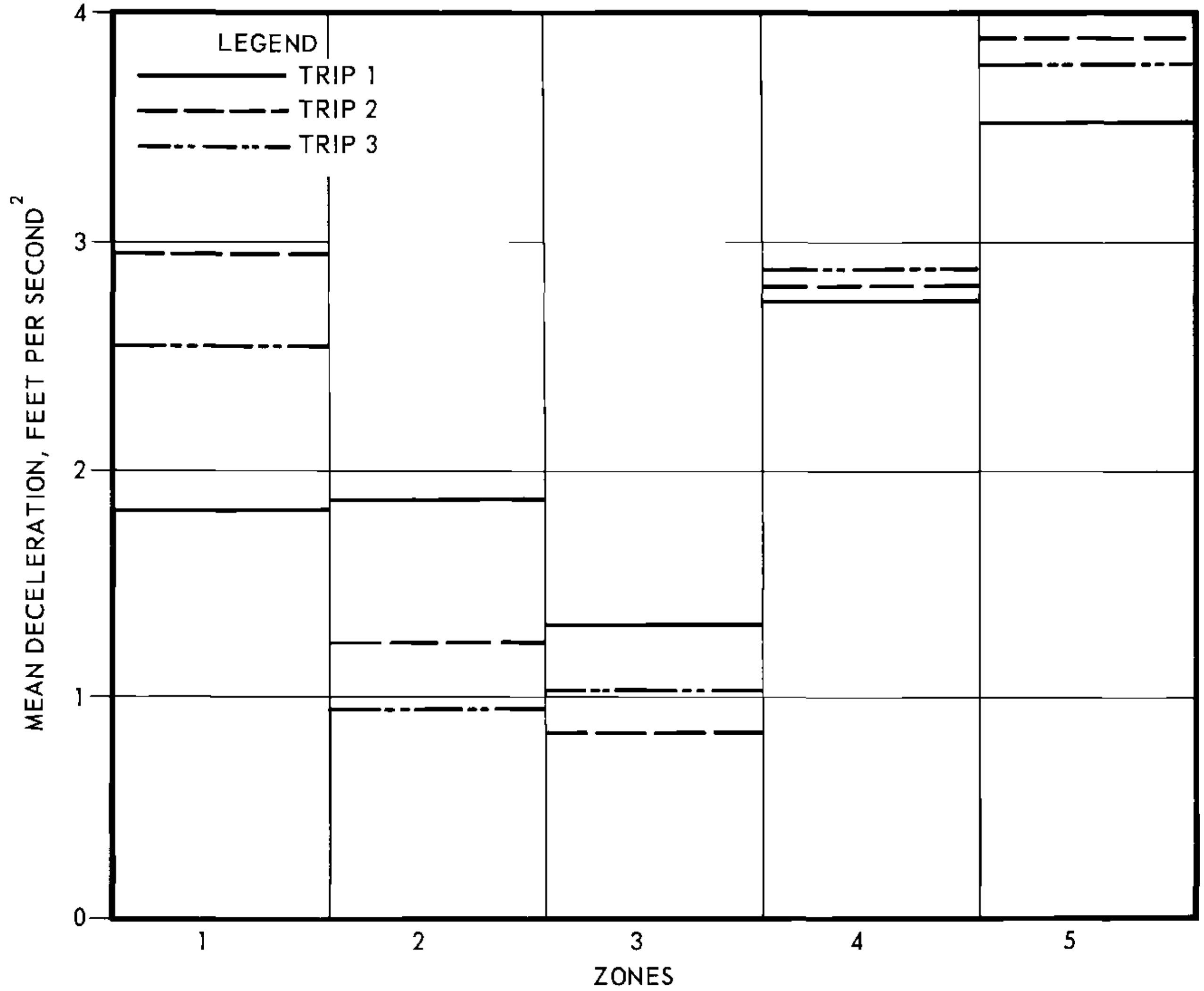

Figure 18. Mean Rate of Deceleration During Each Trip.

Figure 5. Rank Order and Significant Differences Between Test and Control Groups for the Dependent Variable "Deceleration" (Significance Level 10 Per Cent)

Zone	Lowest				Highest	
1	Test 1	Test 5	Test 2	Test 4	Test 3	Control
2	Control	Test 4	Test 3	Test 2	Test 1	Test 5
3*	Test 2	Test 3	Test 5	Test 4	Control	Test 1
4	Test 1	Test 5	Test 4	Test 3	Test 2	Control
5	Test 1	Test 2	Test 3	Test 5	Control	Test 4

There are no significant differences between those conditions underlined.

*The significant ranges for this position were not detectable with Scheffe's procedure, and were estimated using Duncan's procedure assuming equal number of observations in the subclasses.

Analysis of Variance--Lateral Placement Data. In view of the limitations of the lateral placement data produced by the by-passing of the placement traps at position 2 and 5, the analysis of variance results must be interpreted with caution.

No analysis of variance was performed on the placement data at position 1 because of the placement of test vehicles in both the median lane and the outside travel lane of the freeway, and because of the limited number of data available at this position.

Table 6. Rank Order and Significant Differences Between Trips for the Dependent Variable "Deceleration" (Significance Level 10 Per Cent)

Zone	Lowest		Highest
1	Trip 1	Trip 3	Trip 2
2	Trip 3	Trip 2	Trip 1
3	Trip 2	Trip 3	Trip 1
4	Trip 1	Trip 2	Trip 3
5	Trip 1	Trip 3	Trip 2

There are no significant differences between those conditions underlined.

The analysis of variance indicated significant differences between vehicle placements of the test and control groups at positions 3, 4, 5, and 7, and no significant difference at position 2. The vehicle placements during the three trips were significantly different at all positions, except position 5. The results of the analysis are tabulated in Appendix B.

The results of the comparison tests between vehicle lateral placements of the test and control groups and of the three trips are shown in Tables 7 and 8, respectively. The vehicles in test group 3 were found to be travelling significantly nearer to the outside or shoulder edge of the pavement than test group four at positions 3 and 7, and significantly nearer than the control group at position 4. At position 5, the beginning of the full-width deceleration lane, vehicle placements in test group four were significantly nearer the outside edge of the lane than the control group vehicles. It was at this position that the highest frequency of vehicles by-passing the traps occurred.

Table 7. Rank Order and Significant Differences Between the Test and Control Groups for the Dependent Variable "Lateral Placement" (Significance Level 10 Per Cent)

Position	Lowest					Highest
1	(Not Analyzed)					
2	Test 2	Test 3	Test 5	Test 4	Test 1	Control
3	Test 3	Test 2	Test 1	Test 5	Control	Test 4
4	Test 3	Test 2	Test 1	Test 5	Test 4	Control
5	Test 4	Test 1	Test 5	Test 2	Test 3	Control
6	(No data collected at this position)					
7	Test 3	Test 1	Test 5	Control	Test 2	Test 4

There are no significant differences between those conditions underlined.

The vehicle lateral placements during the first trip was significantly farther from the outside edge of the pavement at positions two and three than during the second and third trips. Vehicle placements were also significantly farther from the edge during trip one than

Table 8. Rank Order and Significant Differences Between Trips for the Dependent Variable "Lateral Vehicle Placement"

(Significant Level 10 Per Cent)

Position	Lowest		Highest
1	(Not Analyzed.)		
2	Trip 2	Trip 3	Trip 1
3	Trip 3	Trip 2	Trip 1
4*	Trip 3	Trip 2	Trip 1
5	Trip 3	Trip 1	Trip 2
6	(No Data Collected at this Position.)		
7	Trip 2	Trip 3	Trip 1

There are no significant differences between those conditions underlined.

*The significant ranges at this position were not detectable with Scheffe's procedure and were estimated using Duncan's procedure assuming equal number of observations in the subclasses.

during trip two at position seven. There were no significant differences in lateral placements between the three trips at position five.

Secondary Experiment

The analysis of the secondary experiment consisted of the determination of significant differences between the test and control vehicles for the three experimental conditions. All data pertaining to the secondary experiment were obtained at the observation station positioned at the Howell Mill Road interchange. The results of the analyses are shown in Table 9.

Table 9. Rank Order and Significant Differences Between the Test and Control Groups for the Dependent Variable "Speed" Under Different Experimental Conditions (Significance Level 10 Per Cent)

Condition	Lowest	Highest
Disabled Vehicle	TEST	CONTROL
Grass Cutting	TEST	CONTROL
Route Information	TEST	CONTROL

There are no significant differences between those conditions underlined.

As indicated in the foregoing table the vehicle speeds of the test and control groups were found to be not significantly different during the "route information" and the "disabled vehicle" experiments. During the "grass cutting" activity, however, the test vehicle speeds were found to be significantly lower than the control vehicle speeds.

CHAPTER IV

SUMMARY OF RESULTS AND CONCLUSIONS

Summary of Results

The results of the analysis of variance of the data are summarized below. In this summary all discussions regarding significant or nonsignificant differences between speeds, rates of deceleration, and lateral placements, refer to the differences between average values of the speeds, decelerations and placements of each test or control group.

Primary Experiment

1. The analysis of variance indicated that at a distance of 0.4 miles in advance of the exit terminal the vehicle speeds of any of the five test groups and the control group were not significantly different from any of the others.

2. At a point 50 feet in advance of the beginning of the deceleration lane the speed of the through traffic vehicles was found to be significantly greater than the test vehicle speeds.

3. The speed of the test vehicles during test condition three were found to be significantly greater than the vehicles' speeds during test condition one at all positions near the exit terminal except at positions three and seven. These latter observation positions were located near the beginning of the tapered section of the deceleration lane and on the exit ramp, respectively.

4. Similarly the control group vehicle speeds were found to be significantly greater than the speeds of the test vehicles in group one at all positions except position six and seven.

5. At position five, located at the beginning of the full-width deceleration lane, the vehicle speeds of all groups except test group four were found to be significantly greater than the vehicle speeds in test group one.

6. The analysis of variance indicated that the significant differences in vehicle speeds at all positions, except on the exit ramp, were differences between test group one and one or more of the other groups. Thus with the exclusion of group one, no significant differences in vehicle speeds existed between the test groups and the control group at any of the positions except on the exit ramp.

7. No significant differences in vehicle speeds were found to exist between the three successive trips at the positions just in advance of and along the tapered section of the deceleration lane.

8. At the positions along the full-width deceleration lane and on the exit ramp, vehicle speeds during trip one were significantly lower than the speeds during trip two. Vehicle speeds during trip three were intermediate and not significantly different from the vehicle speeds during either trip one or two.

9. The analysis of the deceleration data showed that no significant differences existed between the rates of deceleration of the test and control group vehicles in the first two zones along the exit terminal.

10. In zone three, the rate of deceleration of the vehicles in

test group one and the control group were found to be significantly higher than the rate of deceleration of the vehicles in test group two.

11. In zones four and five, the vehicles' deceleration rates of test group one were found to be significantly lower than the deceleration rates of the control group. In zone five, the deceleration rates of test group one were also found to be significantly lower than the rates of deceleration of test group four.

12. The analysis indicated that in zone one the vehicle deceleration rates during trip one were significantly lower than during trip two.

13. In zones two and three, along the tapered section of the deceleration lane the vehicle deceleration rates during trip one were significantly greater than during trip three.

14. No significant differences were found in the deceleration rates during the three trips in zones four and five.

15. The analysis of the lateral placement data showed that there were no significant differences between the vehicle placements of any of the five test groups and the control group at position two.

16. The vehicle placements in test group three were found to be significantly nearer the pavement edge than the vehicles in test group four at positions three and seven, and similarly nearer the pavement edge than the control group vehicles at position four. None of the other groups had consistently significant differences in vehicle placements at two or more positions.

17. The analysis indicated that at positions two and three the

vehicles were positioned significantly farther from the pavement edge during trip one than during trip two and three. At position four the vehicle placements during trip three were still significantly different from the placements during trip one, but the placements during trip two were intermediate and not significantly different from trip one and three.

18. At the beginning of the full-width deceleration lane the vehicle placements during the three trips were not significantly different.

19. On the exit ramp vehicle placements during trip two were found to be significantly nearer the pavement edge than during trip one.

Secondary Experiment

1. The analysis indicated significantly different vehicle speeds between the test and control vehicles during the grass cutting experiment.

2. No significant difference between test and control vehicle speeds were found during the disabled vehicle and general route information experiment.

Conclusions

Primary Experiment

1. The provision of radio roadside communication in addition to standard advance highway signing did not significantly affect the speed at which motorists travelled at a point approximately one-half mile in advance of the exit terminal as compared to vehicle speeds of

motorists travelling under conditions of standard advance highway signing only.

2. When the guidance information consisted of both advance and exit information either standard highway signs, or combinations of audio messages and signs, the manner in which the motorists operated their vehicles did not differ significantly in either vehicle speeds or rates of decelerations along the deceleration lane.

3. When the guidance information consisted of the standard advance highway sign only, motorists travelled at significantly lower speeds throughout the length of deceleration area than motorists travelling under conditions of standard advance and exit signing supplemented with advance and exit audio messages.

4. The significant differences between vehicle speeds during trip one and two and the non-significant difference between vehicle speeds during these two trips and trip three indicate the probable existence of a decreasing oscillatory speed adjustment due to the cumulative experience gained during the preceding trips.

5. The motorists commenced the execution of the exit maneuver at a point in advance of the beginning of the deceleration lane as evidenced by the significant differences in vehicles' speeds, between through-traffic and the test vehicles exiting the highway.

Secondary Experiment

1. Roadside radio communication was indicated to be an effective device in warning motorists of potential hazards along the highway as evidenced by significantly different vehicle speeds between test and control drivers during the grass cutting experiment.

2. The non-significant difference in speeds between the test and control vehicles during the disabled vehicle experiment indicates the possibility that, because of the frequency with which the urban motorists encounter disabled vehicles, this situation is not considered potentially hazardous by the drivers.

Recommendations

In view of the results of this research and the results indicated in Annual Report No. 1(1) the logical direction for additional and more intensive research is the evaluation of this mode of communication of an experimentally feasible systems basis over a protracted period of time while providing driver information regarding potentially hazardous roadway conditions. Research in this area would yield a realistic preliminary cost estimate on a system basis and this more comprehensive treatment would provide more conclusively specific areas of feasibility of roadside radio communications.

An alternative short term research project would be the investigation of the effect of radio communications for driver information and traffic control during night time conditions. A similar experiment as the one described in this report but conducted during night time conditions would provide direct comparisons of standard visual guidance and audio guidance under conditions of limited visibility.

APPENDIX

APPENDIX A

NUMBER OF TEST SUBJECTS OBSERVED PER TRIP FOR EACH TEST AT EACH POSITION, AND NUMBER OF TEST VEHICLES BY-PASSING THE TRAFFIC ANALYZER TRAPS

Table A-1. Number of Vehicles for Which Speed Data Were Obtained During Each Trip, Each Test Condition and for Each Position (Primary Experiment)

Test Number	Position Number	Trip Number 1	2	3
1	1	6	7	6
	2	8	20	20
	3	8	16	16
	4	8	17	16
	5	7	17	19
	6	6	14	20
	7	8	20	20
2	1	14	2	15
	2	28	25	28
	3	15	23	18
	4	16	23	19
	5	27	17	27
	6	27	23	27
	7	28	25	28
3	1	1	9	11
	2	24	24	19
	3	18	19	14
	4	18	20	13
	5	23	22	19
	6	24	22	19
	7	24	24	19
4	1	8	1	3
	2	19	16	15
	3	15	17	10
	4	14	17	10
	5	16	16	13
	6	19	18	14
	7	20	18	15
5	1	12	14	6
	2	24	24	15
	3	13	14	11
	4	13	15	11
	5	17	20	13
	6	23	23	11
	7	23	24	15
Control	1	25	22	28
	2	30	30	30
	3	29	30	29
	4	29	30	29
	5	24	24	25
	6	27	28	24
	7	30	30	30

Table A-2. Number of Vehicles for Which Deceleration Data Were Obtained During Each Test Condition and for Each Zone (Primary Experiment)

Test Number	Zone Number	Trip Number 1	2	3
1	1	8	15	16
	2	8	16	16
	3	7	14	15
	4	6	12	19
	5	6	14	20
2	1	14	23	18
	2	14	23	18
	3	14	15	18
	4	27	17	27
	5	27	23	27
3	1	18	18	13
	2	18	18	13
	3	17	20	13
	4	23	22	19
	5	24	22	19
4	1	14	15	10
	2	14	17	10
	3	12	15	8
	4	17	16	13
	5	19	18	14
5	1	13	14	11
	2	13	14	11
	3	9	13	9
	4	17	20	10
	5	23	23	11
Control	1	29	30	29
	2	29	30	29
	3	23	24	24
	4	23	24	23
	5	27	28	23

Table A-3. Number of Vehicles for Which Lateral Placement Data Were Obtained During Each Trip, Each Test Condition, and for Each Position (Primary Experiment)

Test Number	Position Number	Trip Number 1	2	3
1	1	6	7	6
	2	8	20	20
	3	8	16	16
	4	8	17	16
	5	1	17	19
	6			
	7	8	20	20
2	1	14	2	15
	2	28	25	28
	3	15	23	18
	4	16	23	19
	5	27	17	27
	6			
	7	28	23	28
3	1	1	9	11
	2	24	24	19
	3	18	19	14
	4	18	20	13
	5	23	22	19
	6			
	7	24	24	19
4	1	8	1	3
	2	19	16	15
	3	15	17	10
	4	14	17	10
	5	1	16	13
	6			
	7	20	18	15
5	1	12	14	6
	2	24	24	15
	3	13	14	11
	4	13	15	11
	5	17	20	13
	6			
	7	23	24	15
Control	1	25	22	28
	2	30	30	30
	3	29	30	29
	4	29	30	29
	5	13	24	24
	6			
	7	30	30	30

Table A-4. Number of Test and Control Vehicles By-Passing the Lateral Placement Traps

Positions	1	2	3	4	5	6	7
Group Number							
1		0			6		1
2		0			6		0
3		0			3		0
4		3			8		0
5		0			12		0
Control		0			17		0

Vehicle lateral placements at positions 1, 3, and 4 were obtained from the film analysis. No lateral placement data was obtained at position 6.

APPENDIX B

ANALYSIS OF VARIANCE RESULTS

Table B-1. Analysis of Variance Results for the Dependent Variable "Speed" Primary Experiment

POSITION 1

Source of Variance	Levels of Significance 5%	10%
Test Condition	Non-Significant	Non-Significant
Trip	Non-Significant	Non-Significant
Test-Trip	Non-Significant	Non-Significant

POSITION 2

Source of Variance	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Non-Significant	Non-Significant
Test-Trip	Non-Significant	Significant

POSITION 3

Source of Variance	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Non-Significant	Non-Significant
Test-Trip	Significant	Significant

POSITION 4

Source of Variance	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Non-Significant	Non-Significant
Test-Trip	Non-Significant	Non-Significant

Table B-1. Analysis of Variance Results for the Dependent Variable "Speed" Primary Experiment (Continued)

POSITION 5

Source of Variation	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Significant	Significant
Test-Trip	Significant	Significant

POSITION 6

Source of Variation	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Significant	Significant
Test-Trip	Non-Significant	Non-Significant

POSITION 7

Source of Variation	Levels of Significance 5%	10%
Test Condition	Non-Significant	Significant
Trip	Significant	Significant
Test-Trip	Non-Significant	Non-Significant

Table B-2. Analysis of Variance Results for the Dependent Variable "Deceleration" Primary Experiment

ZONE 1

Source of Variance	Levels of Significance 5%	10%
Test Condition	Non-Significant	Non-Significant
Trip	Significant	Significant
Test-Trip	Non-Significant	Non-Significant

ZONE 2

Source of Variance	Levels of Significance 5%	10%
Test Condition	Non-Significant	Non-Significant
Trip	Significant	Significant
Test-Trip	Non-Significant	Non-Significant

ZONE 3

Source of Variance	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Non-Significant	Non-Significant
Test-Trip	Non-Significant	Non-Significant

ZONE 4

Source of Variance	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Non-Significant	Non-Significant
Test-Trip	Non-Significant	Non-Significant

ZONE 5

Source of Variance	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Non-Significant	Non-Significant
Test-Trip	Non-Significant	Non-Significant

Table B-3. Analysis of Variance for the Dependent Variable "Lateral Placement" Primary Experiment

POSITION 2

Source of Variance	Levels of Significance 5%	10%
Test Condition	Non-Significant	Non-Significant
Trip	Significant	Significant
Test-Trip	Non-Significant	Non-Significant

POSITION 3

Source of Variance	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Significant	Significant
Test-Trip	Non-Significant	Non-Significant

POSITION 4

Source of Variance	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Significant	Significant
Test-Trip	Non-Significant	Non-Significant

POSITION 5

Source of Variance	Levels of Significance 5%	10%
Test Condition	Non-Significant	Significant
Trip	Non-Significant	Non-Significant
Test-Trip	Significant	Significant

POSITION 7

Source of Variance	Levels of Significance 5%	10%
Test Condition	Significant	Significant
Trip	Significant	Significant
Test-Trip	Non-Significant	Non-Significant

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